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August 1977

TECHNICAL ECONOMIC ANALYSIS OF SELECTED FEATURES OF MUNICIPAL WASTEWATER CONSTRUCTION GRANT LEGISLATION

By

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This report analyzes the current Federal Construction Grant Program for funding the treatment of municipal wastewater. Four main elements of this Federal program are evaluated: the grant formula, the allotment funding process, grant-eligible reserve capacity, and industrial cost recovery. Existing legal provisions with respect to each of these program elements are shown to be deficient in terms of their ability to encourage an efficient allocation of abatement resources and to promote an equitable distribution of Federal grant funds. The report presents several options within each program element for improving the principles of Construction Grant Legislation.

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CHAPTER I

INTRODUCTION

SECTION 317 of the Federal Water Pollution Control Act Amendments of 1972 requires the Administrator of the U. S. Environmental Protection Agency

> ".... to investigate and study the feasibility of alternative methods of financing the cost of preventing, controlling and abating pollution as directed in the Water Quality Improvement Act of 1970 (Public Law 91-224), including, but not limited to the feasibility of establishing a pollution abatement trust fund."

In order to respond to this directive, EPA designed and sponsored several studies to analyze different aspects of the wastewater financing problem. The present study represents one of those efforts.

The objective of this study is to evaluate the cost-effectiveness of selected legislative features relating to the current Construction Grant Program. In this program, the Federal government can subsidize 75 percent of grant-eligible capital costs incurred by municipalities in the construction of wastewater treatment facilities. The criteria used to evaluate the existing program, as well as to generate and evaluate options to this program, include those of effectiveness, efficiency, equity, Federal subsidy cost, and ease of program design and implementation.

Effectiveness is the ability of a program to encourage socially desirable pollution control activities and levels of pollution abatement. Efficiency refers to the capacity of a program to induce the adoption of the least costly methods of achieving any level of pollution control. Equity refers to the inherent fairness of a program, such as its responsibility to distribute grant funds on the basis of factors relevant to the objectives of the program, and in a way that will appropriately take into account differences in fiscal capacity among communities and income classes.

The Federal subsidy cost is simply the government's share of municipal pollution control costs. The ease of program design and implementation refers to the data and resource requirements necessary to initiate and operate a particular program.

The approach taken in this study is to evaluate separately four major elements of the Construction Grant Program: the grant formula, the allotment funding process, grant-eligible reserve capacity, and industrial cost recovery. In this way it is possible to analyze each of the program elements on the basis of a reduced set of relevant criteria. Simultaneously, it is conceptually desirable to initially design a grant program which is both efficient and effective, as well as to consider modifications that take into account other evaluative criteria such as equity, Federal program cost, ease of program administration, etc. If the net social benefits generated by the program are maximized, there is then available more net benefits for everyone, and the distribution of these net benefits and the mechanics of implementing and operating the program can often be determined afterwards. This conceptualization is employed in evaluating each of the four program elements under consideration.

One factor not considered in this report is the transition costs incurred in changing the existing program. Between this omission, data limitations, data uncertainties, and incommensurability from some of the above-stated criteria, it is generally not possible to develop an ordinal ranking of the overall desirability of the alternatives. Despite this limitation, it is feasible to generate sufficient information which will allow us to determine what options are preferable to the status quo as a means for achieving a given objective for a designated program element.

Organization of the Report

The next chapter describes the legislative history of Federal grant programs for funding the collection and treatment of municipal wastewater. Specific details of the current Construction Grant Program are discussed in Chapter III.

The general theory of Federal cost sharing of municipal pollution control costs and projects is developed in Chapter IV. Based on identified shortcomings of the existing Federal grant rate and grant eligibility, Chapter V designs and evaluates alternative grant formulae.

Chapter VI analyzes the allotment funding process for distributing Federal grants initially to the States, and subsequently from the States to local wastewater pollution control projects. Chapter VII calculates the effect upon Federal funding requirements of alternative design period grant eligibilities, to accommodate treatment plant and interceptor sewer reserve capacity.

Chapter VIII quantifies the relationship between industrial participation in public facilities and the share of pollution control costs borne by municipalities. Modifications in the existing industrial cost recovery program element are considered which would tend to reduce the Federal cost of the Construction Grant Program, while at the same time improving the allocation of abatement resources for the treatment of industrial wastewater in public and private facilities.

Findings and Conclusions

This report initially analyzes the ability of potential Federal wastewater cost-sharing programs to induce municipalities to select (1) socially desirable levels of pollution abatement for given wastewater treatment projects, and (2) socially desirable wastewater treatment projects. The analysis indicates that in the absence of a substantial degree of regulation and enforcement (which is currently provided in P.L. 92-500), Federal cost-sharing programs cannot be relied upon to adequately promote either of the above-stated objectives.

In fact, the study shows that designing an economically optimal cost-sharing program is difficult even in theory. When real-world considerations are taken into account, such as limited data on the value of benefits from pollution control, the interdependent relationship among communities between abatement and water quality, and constraints on available Federal and local funds for wastewater treatment, it is clear that cost-sharing programs should be formulated with more modest objectives than the attainment of an economically optimal allocation of abatement resources.

The following objectives of a Federal wastewater cost-sharing program appear to be most appropriate for policy-making purposes: First, the cost-sharing program should encourage municipalities to undertake projects that are cost-effective for society, but which would not be undertaken in total or in part without Federal financial aid. In this way limited cost-sharing funds would be used to supplement, rather than to substitute for municipal funding.

Second, the cost-sharing program should provide an incentive for municipalities to construct and operate the least costly abatement projects, from society's viewpoint, for whatever level of pollution abatement is achieved. Satisfaction of this objective encourages an efficient allocation of resources utilized in controlling pollution. As a result, any disruptive effect of pollution abatement activities on the availability and prices of resources throughout the rest of the economy will be kept to a minimum, and the size of the Federal cost share necessary to support the program may be restrained.

Third, the cost-sharing program should take into account differences in population size and the economic status of municipalities in determining the distribution of Federal grant funds. Ceteris paribus, it would appear desirable that communities with the greatest fiscal capacity to pay for pollution control costs also bear the highest proportion of these costs.

The present Construction Grant Program is deficient as a means for satisfying any of these three objectives. A uniform subsidy rate for all grant-eligible construction costs and projects, as provided by the Construction Grant Program, fails to adequately ensure that municipalities will use Federal funds to undertake those projects that are cost-effective to the nation, but which the communities would not ordinarily undertake without Federal aid. Further, as a result of subsidizing only grant-eligible construction costs, the Federal cost-sharing program generates a preference for municipalities not to choose the least costly pollution control projects. Existing grant-eligibility for reserve capacity and cost recovery provisions relating to industrial use of public facilities further magnify the local preference to overbuild and undermaintain wastewater treatment facilities.

The Federal grant program presently distributes authorized funds to the States on the basis of relative capital costs needed to meet mandated pollution control requirements. There are indications that the funding process might be modified so that only one-half of allotments would be distributed on this basis, and the remaining portion distributed according to relative size of state population. In either of these allotment programs, there is no reason to suspect that limited Federal grant funds (1) will be distributed nationally or even within the States on a cost-effective basis, or (2) will be responsive to the fiscal capacity of the municipalities within the States to pay for the required pollution control projects.

At the same time, owing in part to the cost recovery program, per capita pollution control costs will tend to be lower in more industrialized communities. This result is inequitable on grounds of both relevance to the objectives of the grant program, and in terms of the fiscal capacity of the communities to bear the burden of pollution control costs.

The analysis indicates that the following modifications in the Construction Grant Program would ameliorate a significant portion of the existing deficiencies:

1. Provide higher cost-sharing rates and larger funding authorizations relative to estimated "needs" for wastewater control projects such as secondary and higher-level treatment plants. The benefits generated by treatment projects generally accrue to residents living outside the local community. Accordingly, in the absence of substantial Federal financial aid, these projects are not likely to be voluntarily undertaken by the local community to the socially desirable extent. Wastewater collection projects, such as sewer systems, generate benefits which accrue to a greater extent to residents living within the local community. As such, these projects may be encouraged by a lower level of Federal cost sharing than is required for treatment plant projects.

2. In the absence of a charge for municipal and industrial effluents, supplement the Construction Grant Program with either an operating and maintenance cost subsidy or a subsidy based on the amount of abatement achieved. It is estimated that a 25 percent operating cost subsidy program would currently require less than $300 million annually in grant funds allocated to secondary treatment plants. An abatement subsidy program costing less than $500 million annually in grant funds is expected to reduce the existing effluent of secondary treatment plants by more than 20 percent.

3. Divide the allotment of grant funds into two parts: one part to be disbursed on the basis of an efficiency criterion, the other part according to an equity criterion. The efficiency criterion ranks projects and funding priorities on the basis of the projects' cost-effectiveness. The equity criterion ranks projects and funding priorities according to the communities' pollution control costs relative to their fiscal capacities.

4. Limit the design period for defining grant-eligible reserve capacity from 10 to 12 years for treatment plants, and from 20 to 25 years for interceptor sewers. Compared to the present program, this would reduce the present value of real resource costs necessary to achieve mandated abatement requirements, as well as substantially reduce the size of Federal funding required to pay for existing pollution control needs. This latter saving is estimated to be in the range of $5 to $10 billion, which represents a 20% to 40% reduction in currently projected Federal funding requirements for treatment plants and interceptors.

5. Terminate local retention of industrial cost recoveries collected against the Federal construction grant. Cost recoveries would be returned to the U.S. Treasury or to the Construction Grant Program for redistribution to the highest priority projects. If local retention of cost recoveries is not abolished, then eliminate the local discretionary fund, in which up to 20% of retained cost recoveries can be used to pay for projects unrelated to pollution control. Also, in order to remove the local financial preference to use reserve funds to pay for non-grant related projects, do not deduct the amount of funds held in reserve from grant-eligible project costs in order to determine the size of the Federal grant.

CHAPTER II

LEGISLATIVE HISTORY OF FEDERAL WASTEWATER FINANCING PROGRAMS 1/

This chapter summarizes the salient elements of recent Federal legislation relating primarily to the financing of municipal water pollution control projects. The period covered is 1948 through the present. For our purposes the relevant differences in the Acts concern the allocation of authorized Federal funds to the States and the distribution of these allocated funds to municipalities based on a predetermined Federal share of grant eligible pollution control costs.

Public Law 80-845: 1948

The current version of the Federal Water Pollution Control Act has its roots in Public Law 80-845, passed in 1948, which authorized loans and other assistance to States and municipalities for water pollution abatement. Public Law 80-845 declared it to be the policy of Congress

> "... to recognize, preserve, and protect the primary responsibilities and rights of the States in controlling water pollution, to support and aid technical research to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment, and to provide Federal technical services to State and interstate agencies and to industries, and financial aid to State and interstate agencies and to municipalities, in the formulation and execution of their stream pollution abatement programs." [Section 1]

The Surgeon General of the Public Health Service, the Federal Works Administrator, and the Federal Security Administrator were to administer the program. According to Section 5 of this Act the Federal Works Administrator was authorized to make loans to States, municipalities, or interstate agencies to construct treatment works preventing the discharge of untreated or inadequately treated wastes. Loans could also finance the

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1/ This chapter was prepared by Meta Systems for EPA as part of their report entitled Evaluation of Alternative Methods for Financing Municipal Waste Treatment Works, EPA 600/5-75-001, Washington, D.C., March, 1974.

preparation of engineering reports, plans, and specifications. Loans were to be made only if a project was part of a "comprehensive" plan as well as approved by the Surgeon General and appropriate State agency. Federal loans had an interest rate of two percent and were limited to 33.3 percent of the "estimated reasonable cost" or $250,000, whichever was smaller. Section 5 also provided that:

> "... bonds or other obligations evidencing any such loan (1) must be duly authorized and issued pursuant to State and local law, and (2) may, as to the security thereof and the payment of principal thereof and interest thereon, be subordinated [with agreement of Federal Works Administrator] to other bonds or obligations of the obligor issued to finance such project or that may then be outstanding."

The priority of projects would be determined by the "public benefit to be derived," the "propriety of Federal aid in such construction," the relation of the full costs of construction and maintaining works to public interest and necessity, and the "adequacy of provisions ... for assuring proper and efficient operation and maintenance of the works" after construction.

Public Law 80-845 authorized $22.5 million for loans under Section 5 of this Act for each fiscal year from 1948 to 1953 [Section 7] and $1 million during those years grants in order to complete the preliminary planning and engineering work on approved projects. Public Law 82-579 extended the life of 80-845 until June 1956. The funds, however, were never actually appropriated [1].

Public Law 80-845 was substantially amended in 1955-56, 1961, 1965-66, and 1972. Since 1948, modifications to the water pollution control legislation related to the construction of waste treatment works have focused on several issues: (1) the proper role and authority of States in managing their environmental affairs, particularly waste treatment; (2) the percentage size contribution or cost-sharing proportion the Federal government should provide to State pollution control projects (the grant formula); (3) the distribution formula used to determine how authorized Federal money should be allocated among States and among municipalities of different sizes (the allotment formula); and (4) the criteria or safeguards used to insure efficient use of Federal funds.

Public Law 660: 1955-56

During the 1955-56 Congressional sessions, two bills (S. 890 and H. R. 9540) were introduced to replace Public Law 80-845. In both bills the Surgeon General, through the Public Health Service under the Department of Health, Education, and Welfare (HEW), was authorized to investigate pollution sources and causes, as well as make grants for research, demonstration projects, and training personnel to operate and maintain treatment plants. S. 890 of this Act provided that the Surgeon General would

> "... from time to time make allotments to the several States, in accordance with regulations, on the basis of (1) the population, (2) the extent of the water pollution problem, and (3) the financial need of the respective States." [2]

The Surgeon General also was given the broad power of allocating money to interstate agencies on "such basis as [he] finds reasonable and equitable." [2]

The importance of recognizing and preserving "the primary responsibilities of the States in preventing and controlling water pollution" [2] was emphasized as was the proposed legislation to provide the support and aid in technical research, which was seen as the most effective stimulant to State control programs. HEW officials testified at Senate Public Works Committee Hearings in April, 1955 that "experience with other health programs has demonstrated the value of matching grants in stimulating States to provide their own resources to do an effective job." It was purported that Federal support was most effective in planning, research, consulting, and technical assistance on tasks which most States could not adequately perform but which were critical to the construction of treatment works.

Since matching funds would stimulate State involvement in pollution control, S. 890, Section 5 of this Act constructed a formula for the Federal share of control projects:

> "The 'Federal share' for any State shall be 100 per centum less that percentage which bears the same ratio to 50 per centum as the per capita income of such State bears to the per capita income in the continental United States (except Alaska),

> except that (A) the Federal share shall in no case be more than 66 2/3 per centum or less than 33 1/3 per centum, and (b) the Federal share for Hawaii and Alaska shall be 50 per centum, and for Puerto Rico and the Virgin Islands shall be 66 2/3 per centum."
>
> "The 'Federal share' shall be promulgated... on the basis of the average of the per capita incomes of the States and of the continental United States for the three most recent consecutive years for which satisfactory data are available from the Department of Commerce."

In other words, each State received a share of money based on its average per capita income. The exact percent of project costs that the Federal government would bear was determined by the ratio of the State's average per capita income to the average per capita income of the nation. No State, however, was to receive a share more than 66.6 percent or less than 33.3 percent of the actual cost of the local project.

H.R. 9540, Section 6, provided direct Federal grants to assist municipalities in the construction of sewage disposal facilities, again emphasizing the "established principle of recognizing the primary rights and responsibilities of the States in controlling water pollution." Instead of the construction loans authorized (but never appropriated) in 1948, this bill provided for matching grants to States, municipalities, intermunicipal agencies, and interstate agencies, for the planning and construction of treatment works. Grants were to be limited to 33.3 percent of the estimated "reasonable" cost of construction or $300,000, whichever was smaller. Recognizing some large cities needed amounts that would deplete a State's entire allotment, the legislation specified that at least 50 percent of the funds authorized for treatment works were to be directed to communities with a population of 250,000 or less, with priority given to municipalities that had done advanced planning. The then-current administration did not endorse Section 6 and took the position that the costs for treatment should be borne by the users of the service, not by the Federal government in the form of grants [3]. (Another bill, S. 982, provided for grants of up to 50 percent of the cost of construction.)

The conference and final version of the bills provided that the Surgeon General make grants for construction of "necessary" treatment works and a number of more specific criteria for the awarding of grants. As in the original Federal Water Pollution Control Act, no grant was to be awarded unless the project was approved by the appropriate State water pollution control agency and the Surgeon General; and unless it was included in a "comprehensive" pollution program no grant was to be for more than 30 percent of the estimated reasonable cost or $250,000, whichever was smaller. Consequently, the grantee was responsible for the remaining cost. Applicants had to demonstrate that there would be "proper and efficient operation and maintenance" of treatment works after completion, and treatment operation had to conform to State pollution control plans (Section 6(b)(3)). In making his decision about allocations, the Surgeon General was instructed to consider the public benefits to be derived from the project, the relation of ultimate costs to public necessity, and the adequacy of provisions for operation and maintenance (Section 6(c)).

Fifty percent of appropriated grant sums were to be allotted to States on the basis of the ratio that the population of each State bore to all the population in all States.

The other 50 percent of appropriated funds was to be allotted to each State based on a complicated ratio formula. Each State would receive an allotment determined by dividing the per capita income of the entire United States by the per capita income of each State, adding all 50 quotients so derived, and determining the ratio that each State's quotient bore to the total of the quotients.

The Act authorized $50 million, wherein 50 percent of appropriations were to go to municipalities of 250,000 or less (Section 6(d)). "Construction" was defined to include preliminary planning, engineering and feasibility studies, and improvement or extension of treatment works (Section 6(e)).

The 1955-56 sessions were also presented with a dozen bills providing for the rapid amortization (60 months) by industry of the cost of industrial treatment works, if the facilities were (1) installed on the basis of demand from local governmental bodies and (2) part of an overall program for pollution control. Municipalities had complained that industrial wastes were one of the problems they could not handle through their ordinary residential treatment works. None of these bills, however, were incorporated into Public Law 660.

Federal Water Pollution Control Act Amendments: 1961

In 1961 the major changes made in the Federal Water Pollution Control Act were an increase in annual authorization of funds and a raise of the ceiling on maximum grants to a single project. The Amendments of 1961 increased the annual authorization for construction grants on a graduated scale from $50 million in fiscal year 1961 to $80 million in fiscal year 1962, $90 million in fiscal year 1963, and $100 million for fiscal years 1964-1967 (Section 5(d) in [4]). Again, 50 percent of the appropriated funds were earmarked for cities of 125,000 or under. Maximum grants were increased from 30 percent or $250,000, whichever was smaller, to 30 percent or $600,000, whichever was least expensive. (Section 5(a)).

Several other features were added to the Act. A project serving more than one municipality could be funded by applying the grant formula to each community's portion of the project as if it were a separate enterprise. The sum of the maximum grants or $2.4 million, whichever was smaller, was to be allocated until all applications were funded which met the regulations in effect prior to the Amendments and which were filed with the appropriate State agency during the first twelve months after enactment of the 1961 Amendments.

This Act further provided that all money allotted to States which remained unobligated for six months beyond the eighteen-month allotment period could be reallocated to States having an excess of approved projects (Section 5(c)). The administrative agent of the Federal Water Pollution Control Act, as amended, was transfered from the Surgeon General to the Secretary of HEW.

1966 Amendments: The Clean Water Restoration Act

During the 1966 session of Congress, debate over the Federal Water Pollution Control Act Amendments focused on the formula for granting Federal money to local projects. The testimony at hearings on the large number of bills submitted to amend the Federal Water Pollution Control Act presented an enormous amount of data documenting the increasing demand and critical need for pollution control projects as well as the flaws and biases of the existing legislation [5]. Witnesses described how the 30 percent limit on grants discriminated against both the largest communities and the smallest towns. A needs survey conducted and presented by the Conference of Sanitary Engineers showed that 70 projects in the current backlog of applications would qualify for grants over $600,000 but under $1 million, for a total of $49.6 million if the ceiling for grants were $1 million. Forty other projects would qualify for over $1 million but under $2 million, for a total cost of $183.8 million if the ceiling were $2 million. Eighteen proposed projects were so large that 30 percent of their cost would be $2 million, with a total cost of $255 million. On the other hand, many small towns could not even qualify for maximum grants on the basis of their population counts, nor did they have the capability to finance treatment works on their own [5].

The time required to obtain Federal grants was repeatedly mentioned as a deterrent, since municipalities delayed construction in the hopes of eventually receiving Federal dollars, and approved projects could experience lag times for nearly two years. A number of witnesses stressed the importance of allowing swifter reallocation of monies that were unused.

The magnitude of pollution abatement prompted the introduction of a large number of bills directed to ease the costs of municipal financing of treatment works. Again, on the basis of the burden industrial wastes placed on municipal systems, 66 bills were filed to allow a tax deduction for construction costs of treatment facilities. Another dozen were filed to provide money to help retire municipal bonds. There was also interest in providing money to help train people for the efficient operation and maintenance of new facilities. Debate over several bills during hearings raised the idea of reimbursing States for pre-financing of treatment works.

The bills which eventually became Public Law 89-753 initially authorized increasing the authorization for construction grants to $150 million in 1967, and up to $1.25 billion in 1971 [6]. Again at least 50 percent of the first $100 million appropriated was to go to municipalities of 250,000 or less.

The general allotment formula to States was the same: the first $100 million appropriated during a fiscal year went to States on the basis of population and per capita income weighted equally; sums appropriated above $100 million were to be allotted solely on a population basis with a 10 percent incentive for regional planning of projects. If sufficient funds were available, State allotments were usable for the reimbursement of State or local money used prior to June, 1971, and after June, 1966, for projects built without Federal assistance (if approved) or with less than the allowable Federal share.

The grant allocation formula was changed substantially in this law with a number of built-in incentives attached. The Federal government would provide 30 percent of the cost of treatment works if the State provided 25 percent of the cost. The Federal share would be increased to 40 percent if the State financed 30 percent of the cost. If the State adopted enforceable water quality standards for the waters which the treatment project affected, the Federal share would increase to 50 percent if the State contributed 25 percent. Again, the criteria established in the

1961 Amendments for selecting projects remained the same, with emphasis upon State determination of priority. River basin plans were eligible for a 50 percent Federal share. The ceiling on individual projects was eliminated, and there was a provision included for loans as much as $250 million.

The committee report on the proposed Amendments stressed the need for tax incentives so that industry would treat their own wastes. The existing Act contained a provision for a seven percent investment credit for the acquisition of air or water pollution facilities which was retained in the Amendments with the provision that facilities met Federal and State specifications. (S. 2857 proposed to increase the tax credit to 14 percent, but it was not acted upon [7].)

Water Quality Improvement Act: 1968

In 1968 the grant system was altered to include contracts for as many as 30 years to pay the Federal share of construction costs. Contracts differed from grants in that they provided a loan which could be issued more quickly to cities than a grant. The Federal share could also be eventually recovered. The allotment of these contracts remained the same as the allotment of grants. The monies available for contracts were to be calculated according to the ratio of the population of each State to the population of all the States, with 50 percent of the first $100 million appropriated to go to cities of 250,000 or less. The contracts could be used to pay off municipal bonds which had been originally issued to finance the construction of treatment works. The Act also approved one-time grants for improving the operation of treatment works, on which construction was initiated after passage of the Act. These grants were not to exceed 25 percent of the cost of operating such treatment works, and in no event were to be over 50 percent of the cost of improving operation during a twelve-month period. The authorization for this grant program was $25 million.

Water Quality Improvement Act: 1970

In 1970 a variety of bills were presented to increase the Federal share and the total and annual authorizations for pollution treatment programs. The Administration bill (S. 3472) estimated that $1 billion Federal input was sufficient to cover both the backlog and the increasing needs until 1974. This bill also proposed to reimburse States for prepayment from current appropriations, while a companion bill suggested an Environmental Financing Authority to be managed through the Treasury Department to assist States and localities in borrowing funds they could not obtain through grants. The allocation of funds was to be made on the basis of a new formula which considered population and the severity of local pollution conditions. Sixty percent of the Federal funds was to be allocated by population and income; 20 percent was to go to those States that paid at least 25 percent of the cost of all assisted projects, distributed on a population basis; and 20 percent was to be allocated on the basis of the severity of the water pollution problems and the local ability to use funds for basin-wide plans. The latter 20 percent was considered "discretionary money" to offset the needs of especially large projects; first priority would go to reimburse States that had pre-financed plans. (The 1966 Amendments had encouraged a number of States and localities to pass bond issues or arrange other means to finance the Federal share of costs in anticipation of reimbursement so that by 1969 over $300 million in backlog payments were due [8].)

Another bill, S. 3687, challenged the Administration estimates by proposing to authorize $2.5 billion annually for six years. The formula in this bill was similar to the earlier 1955 bill with the Federal share being 100 percent minus the percentage calculated from ratios of per capita income in individual States to the entire country. At the time, only 16 States were providing the matching shares to raise the Federal share above 30 percent.

The Amendments of 1970 contained Title I -- the Water Quality Improvement Act -- which made few changes in the sections related to construction grants for waste treatment works. The Federal government's responsibility to make grants or contracts related to training students "to enter an occupation which involves the design, operation, and maintenance of treatment works, and other facilities whose purpose is waterquality control" was expanded by the stipulations in newly added Section 16.

The 1970 Amendments (Title II) also replaced the Federal Water Pollution Control Administration with the Federal Water Quality Administration. Authorizations remained at the level voted in 1966, or $1 billion for the fiscal year ending June, 1970 and $1.25 billion for the fiscal year ending June, 1970 and $1.25 billion for the fiscal year ending June 30, 1971.

Public Law 92-500: 1972

The next major alteration of the Federal Water Pollution Control Act came in 1972. Title II, called "Grants for Construction of Treatment Works," expanded the purposes of the Act and specified goals for new technology (including reclamation and recycling). Although Federal financial assistance is not limited to this revised Act (nor were its predecessors the sole source of Federal grant funds for wastewater treatment expenses), the new Act has taken precedence over most other funding sources. Responsibility for administration of the Act has been vested to EPA.

Several new yet general conditions were placed by the 1972 Amendments on the allocation of grants after June 30, 1974, including that:

- Projects provide for the application of the best-practicable waste treatment technology over the life of the works;
- Projects will consider and allow for the application of new technology for reclaiming or recycling water; and
- Each sewer collection system discharging into the treatment works is not subject to excessive infiltration.

The Amendments as finally adopted and passed over the President's veto provide for 75 percent Federal grants for facility construction with no specified State participation required. (The Senate bill provided for a 70 percent Federal grant if the State participated with a 10 percent grant; the House bill provided for a 75 percent Federal grant if the State participated with a 15 percent grant or loan. No State participation would have led to Federal grants of 60 percent under either bill.) The Amendments further provide for an Environmental Financing Authority in order to assure municipal access to funds for financing its share of project costs as well as the allocation of funds among States according to their need for treatment plant construction.

In the next chapter, a more extensive discussion is provided of P.L. 92-500. That discussion will lay the foundation for analysis of those elements of the present financing program which appear in most need of careful scrutiny.

References: Chapter II

1. Hearings of the Senate Committee on Water and Air Pollution Control. U. S. Senate, 84 th Congress, 1st Session, Government Printing Office, Washington, D.C., 1964, p. 52.
2. Water Pollution Control Act Amendments of 1956. Public Law 660, 84th Congress, Chapter 518, 2nd Session, S. 890, Government Printing Office, Washington, D.C.
3. Congressional Record. Government Printing Office, Washington, D.C., June 13, 1956, p. 10240 ff.
4. Federal Water Pollution Control Act Amendments of 1961. Public Law 87-88, 87th Congress, H.R. 6441, Government Printing Office, Washington, D.C., July 20, 1961.
5. Hearings. U.S. Senate Committee on Public Works, Government Printing Office, Washington, D.C., May 19, 1964.
6. Clean Water Restoration Act of 1966. Public Law 89-753, 89th Congress, S. 2947, Title II, Section 205, Government Printing Office, Washington, D.C., November 3, 1966.
7. Congressional Record. 89th Congress, Government Printing Office, Washington, D.C., October 17, 1966, p. 27247.
8. Senate Public Works Committee Hearings. Subcommittee on Air and Water Pollution, Government Printing Officer, Washington, D.C., April 20, 1970, p. 250.

CHAPTER III

DESCRIPTION OF THE CURRENT FEDERAL WASTEWATER FINANCING PROGRAM 1/

Grants for construction of municipal wastewater treatment works are presently authorized under Title II of Public Law 92-500, officially designated as the Federal Water Pollution Control Act Amendments of 1972. Hereinafter, this legislation is referred to as the 1972 Act or the 1972 Amendments. According to Sec. 201(g)(1),

> "The administrator is authorized to make grants to any State, municipality, or intermunicipal or interstate agency for the construction of publicly owned treatment works."

In addition to the enabling legislation, the grant process is further governed by regulations contained in the Code of Federal Regulations under Title 40, Sec. 35.900 *et seq*. (Final Construction Grant Regulations appear in [1].)

As expressed in EPA literature, the objective of the Construction Grant Program is "to assist and serve as an incentive in construction of publicly owned treatment works which are required to meet State and Federal water quality standards [2]." This objective is satisfied by the sharing of construction costs of wastewater treatment facilities with municipalities (i.e., cities, towns, boroughs, counties, parishes, districts--except school districts), associations, management agencies, and other public bodies created by or pursuant to State law and having jurisdiction over disposal of sewage.

The most significant features of the current Construction Grant Program are authorizations, allotments, facility planning, application and approval of grant awards, project priority lists, eligible costs and projects, grant percentage, and user fees. Each of these elements are discussed briefly.

Authorizations

The 1972 Act provided for authorizations of $5, $6, and $7 billion for fiscal years ending June 30, 1973, 1974, and 1975, respectively. However,

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1/ The material in this chapter derives from two original works: The previously cited Meta Systems study on alternative financing methods, and a report written for EPA by the National Bureau of Standards entitled *Analysis of Cost Sharing Programs for Pollution Abatement of Municipal Wastewater*, EPA-600/5-74-031, Washington, D.C., November, 1974.

one-half of these authorizations, that is $9 billion, were impounded by the President. The U. S. Supreme Court has recently ruled that the impoundment of these funds was illegal. Consequently, $9 billion in supplemental authorizations will be made available for construction grants during the period 1975 through 1977.

Allotments

Grant awards for 1973 and 1974 fiscal year Federal funds are to be allocated among the States in the ratio of the estimated cost of constructing all needed publicly owned treatment works in each State to the estimated cost of construction of all needed publicly owned treatment works in all of the States (Public Law 92-500, Section 205(a)). Cost estimates are to be based on a "Needs Survey" for public wastewater treatment works taken in 1971, and published in the House of Public Works Committee Print 92-50.

The allotment of fiscal year 1975 Federal funds has been revised as follows [3]: half of each State's share is based on the ratio of the individual State's total construction needs up to 1990 to the total of all States total construction needs. The other half is based on the ratio of the individual State's costs to all State's cost for the following three specific categories of pollution control facilities: secondary waste treatment plants; advanced waste treatment facilities to meet water quality standards; and new interceptors, forced mains, and pumping stations. In addition, the formula provides that no State will receive less funds than it received in fiscal year 1972. Cost estimates are to be based on the 1973 "Needs Survey" [4].

State allotments are available for a period of one year following the close of the fiscal year in which the sums were authorized. Funds remaining unobligated at that time are reallocated to the other States on the basis of the most recent allotment ratio. Funds obligated but remaining after final payment or project termination are credited to the State as an additional allotment sum. An evaluation of the present allotment formula and suggestions for alternatives are presented in Chapter VI.

Facility Planning

The EPA Grant Program makes awards for any or all of the following three steps: (1) Facilities Planning, during which the applicant's problem is investigated in detail, existing facilities are assessed, alternative approaches to problem solving are evaluated, and environmental impact and cost-effectiveness studies are made; (2) Preparation of Detailed Construction Plans and Specifications, during which the facilities are planned, public hearings are held, and blueprints prepared; and (3) Construction, during which the facilities are built.

Grants may be awarded for Step 1, Step 2, and Step 3, or occasionally for projects that combine Steps 2 and 3. However, Step 2, Step 3, or Step 2 and 3 projects may be funded only if facilities planning (Step 1) requirements have been previously satisfied.

Facilities planning requirements include description of the complete wastewater treatment system; sewer system evaluation; cost-effectiveness analysis including an environmental assessment, comments of agencies with reference to specified planning requirements; description of public reaction; legal, financial, and managerial capabilities statement; and, a civil rights statement.

Best-practicable waste treatment technology must serve as the minimum basis for planning and design in order to obtain grants from funds authorized for any fiscal year beginning after June 30, 1974. In cases where the application of best-practicable treatment would not meet water quality standards, the plan must provide for that level of treatment which will meet the standards.

Grant Application and Approval

The application and approval process is such that after determining that a problem exists, the applicant, perhaps a town represented by its mayor, makes an initial inquiry in its State water pollution control agency. (The title of the State office varies from State to State; e.g., in Alabama it is the Water Improvement Commission; in Kansas, the Division of Environmental Health, State Department of Health; and in Washington, the Washington State Department of Ecology.) The State office hears the inquiry and ordinarily suggests that the applicant make a formal application for a Step 1 Grant. Upon approval, the town assesses its existing wastewater disposal facilities, existing and projected waste loads, and alternative approaches which it might utilize to deal with its problem--typically alternative plant processes and facilities. The plans are submitted to the State agency which evaluates them. It is also responsible for coordinating them with other wastewater disposal efforts in the area. Grants for subsequent steps may be made either as amendments to the original grant application or separately. The State office and/or the EPA regional office may complement the award process with an investigation pertaining to the functioning of the facilities which were constructed.

Many requirements must be met in order to obtain grant approval. Generally, these requirements include the presentation of plans which (1) meet certain grant and physical plant criteria; (2) consider priority and allotment conditions; (3) ensure that the necessary permits have been secured and relevant regulations and laws complied with; (4) do not violate certain cost specifications. A more detailed list of requirements is outlined below:

(a) A facilities plan has been approved before award of Step 2 or Step 3 grant funds.

(b) Proposed works are in conformity with any approved Section 303(e) basin plans.

(c) The priority of proposed works is State certified.

(d) A grant award will not augment the total of all grants to that State's applicants to more than the State's allotment.

(e) The applicant agrees to pay all non-Federal project costs.

(f) A copy of the National Pollutant Discharge Elimination System (NPDES) permit will be provided.

(g) User charge and industrial cost recovery regulations will be complied with.

(h) The proposed site will be available and the Relocation and Land Acquisition Policies Act of 1970 as well as other Federal regulations or statutes will be complied with.

(i) National Environmental Policy Act (NEPA) environmental impact assessments have been performed.

(j) The Civil Rights Act of 1964 has been complied with.

(k) Satisfactory provision has been made to assure that the operation and maintenance monitoring program will comply with applicable permit and grant specifications.

(l) If the project includes sewage collection system work, such work is either for replacement or major rehabilitation of an existing sewer system and is necessary to the performance of the wastewater treatment works, or is for a new sewer system in a community in existence as of October 18, 1972, (where the bulk of the expected flow in the system will originate from the community habitation in existence on that date) with sufficient existing or planned capacity to adequately treat such collected sewage.

(m) Fiscal year 1975 or later grants are for the best-practicable wastewater treatment technology over the lifespan of the works.

(n) Project costs do not include costs allocable to treatment of pollutants in industrial wastes unless the applicant is required to remove such pollutants introduced from non-industrial sources; costs allocable to treatment of wastes from Federal government activities which another Federal agency has agreed to pay. Eligible project costs are reduced by the unexpended balance of the amounts retained by the applicant for future reconstruction and expansion pursuant to industrial cost recovery regulations, together with interest earned thereon.

(o) Initiation of construction has not occurred.

(p) The applicant is the designated Section 208(d) area wastewater treatment management agency if one has been so designated.

(q) The proposed treatment works will comply with all Federal and State environmental laws, including the Clean Air Act.

(r) Each sewer system discharging into the treatment works is not and will not be subject to excessive infiltration and inflow. Validation requires an infiltration/inflow analysis and, when necessary, a sewer system evaluation survey followed by rehabilitation of the sewer system.

(s) A sewer use ordinance will be enacted and enforced which prohibits any new connections from inflow sources into the sanitary sewer portions of the sewer system and ensures that the new sewers and connections are properly designed and constructed.

(t) Industrial pre-treatment requirements will be met.

Grant Award

Eligible public bodies apply for grants through their State water pollution control office. The State office must review each application, coordinate the plans outlined with other relevant projects in the State, make recommendations for changes and, if the plan is approved, then place the application on a priority list which shall be sent to the EPA Regional Administration. There are ten EPA regional offices from which the grant award is made. The total amount of grants made to applicants in a State is limited by the State's allocation of grant funds.

Approval of a grant application constitutes a contractual obligation of the Federal government to pay its share of eligible project costs. Grants are made directly to the municipality.

In addition to the grant conditions already enumerated, further conditions are imposed on grant awards: these include provision for an operation and maintenance plan, including a manual, an emergency response program, properly trained personnel, adequate budget, operational reports, and laboratory testing; as well as the institution of a program for the utilization of small and minority businesses in the case of grants over $10,000,000.

Project Priority Lists

The order of priority for grants received by applicants is ordinarily determined by the State priority ranking criteria. Evaluations and priority line-ups made by the State water pollution control offices are based on EPA guidelines and State guidelines which have been approved by the EPA Regional Administrator. Provisions of the 1972 Act and EPA regulations and guidelines establish some mandatory criteria for project approval as well as certification of priority for grants by State offices, allowing other criteria to be determined by the State with the concurrence of EPA. For the most part, the State options are intended to allow for environmental or other relevant distinctions among areas.

Preparation of the priority list involves five stages: (1) Annual State assessment of water pollution problems and control strategies; (2) Ranking of State water segments taking into account severity of pollution problems, population affected, need for preservation of high-quality waters, and other national priorities; (3) Submission of the municipal discharge inventory list prepared according to Section 303(e) guidelines; (4) generation of criteria for project selection, reflecting water segment factors; and (5) Application of stage 4 criteria to the stage 3 discharge inventory, but including only projects that can be funded from current allotments.

Regional Administrators have been advised to accept or reject project priority lists depending upon whether the States have ranked projects in a manner that is generally consistent with the following sequence [5]:

(a) Projects which are required in order to meet existing water quality standards or otherwise comply with the enforceable provisions of the law--i.e., treatment works that provide secondary treatment or any higher level of treatment dictated by standards. Included in this category are ancillary improvements which must be done in conjunction with an award, such as a cost-effective solution to certified, excessive infiltration into sewers.

(b) Projects which are not required to meet water quality standards but which must be installed to comply with the enforceable provisions of the law--i.e., treatment works that provide secondary treatment. This would include ancillary improvements as described in class (a) above.

(c) Projects against which the enforceable provisions of the law, best practicable treatment, will not be applied until 1983, or against which many water quality standards will not be applicable until 1983--storm and combined sewers. Storm and combined sewer projects will be subject only to the treatment requirements necessary to meet water quality standards. At the request of a State, projects to correct combined/storm sewers if necessary to achieve existing water quality standards, where this is cost effective and practical by the 1977 date for achievement of standards, can be given a higher priority in the FY 1975 list.

(d) Projects which are not discharges--e.g., collection sewers or recycled water supply facilities -- are to receive lowest priority. Collection sewers can be given higher priority when there is an existing groundwater contamination, or problem when they are an integral part of a waste treatment system (which includes a treatment plant) for a community which previously was without such a system.

Furthermore, it is specifically stated that this ranking "does not mean that all projects in class (a) must be funded before initiating projects in class (b), and so forth; nor does it mean that projects must be funded in sequential order."

Public hearings must be held on project priority lists and subsequent modifications thereto. (This requirement is waived for fiscal year 1974 fundings if time is insufficient, and may be waived for modified lists in the future.) The lists are submitted to Regional Administrators within 60 days of any allotment of funds to the States; the Regional Administrator has 30 days to act.

Eligible Costs and Projects

Those project costs which are eligible for funding in the current Federal grant program include: salaries and consultant services; materials and laboratory supplies; preparation of construction reports and drawings; planning, compliance, and evaluation costs; as well as costs related to physical relocation, construction, and landscaping. Costs that are not eligible are for expenses not directly related to the project. They include project completion bonuses; personal injury compensation; fines, penalties, or interest; local operating and maintenance expenses; and site acquisition. Complete lists for both eligible and ineligible costs are presented in Table III-1.

In reference to eligible projects, an important issue is whether nonplant wastewater treatment techniques are fundable under the construction grant program. Nonplant techniques are defined as abatement methods applied outside of the treatment plant and the main interceptors leading into the plant. These techniques, among many, are (1) control and modification of the non-interceptor sewer system, (2) separation of storm and wastewater collection systems, (3) land disposal, and (4) community septic tanks. A complete list of both plant and nonplant abatement techniques is presented in Table III-2.

Table III-1.
Eligible and Ineligible Project Costs Under the Construction Grant Program

1. **Eligible Costs:**

Costs of the grantee which are reasonable and necessary are eligible. Necessary costs may include but are not limited to:

(a) Costs of salaries, benefits, and expendable material incurred by the grantee for the project.
(b) Costs under construction contracts.
(c) Professional and consultant services.
(d) Facility planning directly related to the treatment works.
(e) Sewer system evaluation.
(f) Project feasibility and engineering reports.
(g) Relocation and land acquisition costs required pursuant to the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, 42 U.S.C. 4621 *et seq.*, 4651 *et seq.*, and regulations issued thereunder.
(h) Costs of complying with the National Environmental Policy Act, including costs of public notices and hearings.
(i) Preparation of construction drawings, specifications, estimates, and construction contract documents.
(j) Landscaping.
(k) Supervision of construction work.
(l) Removal and relocation or replacement of utilities, for which the grantee is legally obligated to pay.
(m) Materials acquired, consumed, or expended specifically for the project.
(n) A reasonable inventory of laboratory chemicals and supplies necessary to initiate plant operations.
(o) Development and preparation of an operation and maintenance manual.
(p) Project identification signs.

Table III-1. (Continued)

2. Ineligible Costs:

Costs which are not necessary for the construction of a treatment works project are ineligible. Such costs include, but are not limited to:

(a) Basin or areawide planning not directly related to the project.
(b) Bonus payments not legally required for completion of construction in advance of a contractual completion date.
(c) Personal injury compensation or damages arising out of the project, whether determined by adjudication, arbitration, negotiation, or otherwise.
(d) Fines and penalities resulting from violations of, or failure to comply with, Federal, State, or local laws.
(e) Costs outside the scope of the approved project.
(f) Interest on bonds or any other form of indebtedness required to finance the grantee's share of project costs.
(g) Ordinary operating expenses of local government, such as salaries and expenses of a mayor, city council members, or city attorney; except as provided in Section 35.940-4 of the Grant Program Regulations, for allowance of indirect costs of the grantee in accordance with an indirect cost agreement negotiated and incorporated in the grant agreement.
(h) Site acquisition (for example, sewer rights-of-way, sewer treatment plant sites, sanitary landfills and sludge disposal areas); except as provided in Section 35.950-3(a) for land which will be an integral part of the treatment process or that will be used for ultimate disposal of residues resulting from such treatment, if approved by the Administrator.
(i) Costs for which payment has been or will be received under another Federal assistance program.
(j) Costs of equipment or material procured in violation of Section 35.938-4(b), which provides for award to the low responsive, responsible bidder.

Source: Reference [1].

Table III-2.

Alternative Techniques for Abating Wastewater Pollution

I. Wastewater Prevention, Control, and Reduction Techniques

  A. Prior to Discharge into Waterway

    1. Reduction in Water Use
    2. Active Control and Modification of the Sewer Collection System
      a. Injection of High Molecular Weight Polymers into the Collection System
      b. Selective Retention and Control of Flow in the Collection System
      c. Pretreatment in the Collection System
      d. Controlled Flushing of Sewers
    3. Enhancement of New and Rehabilitation of Existing Collection Sewers
      a. Enlargement of Sewers
      b. Separation of Storm and Wastewater Collection Systems
      c. Design and Construction of Collection System to Prevent Infiltration and Inflows
    4. Control and Restrictions on the Release of Certain Substances into the Sewer System
    5. Influence on Decisions of Households and Industry to Connect to the Municipal Sewer System

  B. During and After Discharge into Waterway

    1. Selective Routing of Effluent Discharge
    2. Low-Flow Augmentation of Receiving Waters

II. Wastewater and Effluent Treatment Techniques

  A. Prior to Discharge into Waterway

    1. Treatment in Conventional and Advanced Waste Treatment Plants
    2. Land Disposal of Wastewater
    3. Community Septic Tanks
    4. Raw Sewage Lagoons

  B. During and After Discharge into Waterway

    1. In-stream Aeration
    2. Treatment of Overflow

A review of the Act reveals a number of passages which suggest inclusion of nonplant techniques for grant consideration. Recalling that the Act authorizes grants for construction of publicly owned treatment works, consider how "treatment works" are defined in Section 212(2)(A):

> "The term 'treatment works' means any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature ... or necessary to recycle or reuse water at the most economical cost over the estimated life of the works, including intercepting sewers, outfall sewers, sewage collection systems, pumping power, and other equipment, and their appurtenances; extensions, improvements, remodeling, additions, and alternations thereof; elements essential to provide a reliable recycled supply such as standby treatment units and clear well facilities; and any works, including site acquisition of the land that will be an integral part of the treatment process or is used for ultimate disposal of residue resulting from such treatment."

Section 212(2)(B) adds the following items to the definition of treatment:

> "... any other method or system for preventing, abating, reducing, storing, treating, separating, or disposing of municipal waste, including storm water runoff, or industrial waste, including waste in a combined storm water and sanitary sewer systems."

This is indeed a very broad definition which would appear to include practically every technique imaginable by which water pollution from municipal waste and storm water could be abated. Similarly, the definition of construction, as given in Section 212(2), does not limit grants to a particular kind of "treatment works."

Other passages of the 1972 Act emphasize that projects for which grants are awarded should use the most cost-efficient alternatives (See, for example, Section 212(2)(c)). The intent appears to be to encourage the most efficient technique, regardless of whether it be "plant" or "nonplant."

There are, however, other passages in the 1972 Act which might be interpreted to prohibit consideration of some nonplant techniques.

Most important to the restrictive interpretation of eligibility are the requirements in the law for a non-polluting discharge and provision of the best-practicable waste treatment technology (now generally defined as secondary treatment) before any discharge into receiving waters. The requirements are contained in the following passages:

> Section 201(b): "Waste treatment management plans and practices shall provide for the application of the best practicable waste treatment technology before any discharge into receiving waters..."
>
> Section 301(b)(1): "There shall be achieved ... for publicly owned treatment works in existence on July 1, 1977, or approved ... prior to June 30, 1974 ... effluent limitations based upon secondary treatment..."

"Before any discharge into receiving waters" is sometimes interpreted to mean disallowing grants for techniques whose application occurs after the sewer outfall system. Accordingly, low-flow augmentation and in-stream aeration are ineligible for grants.

The above sections place significant emphasis on treatment as opposed to other forms of abatement. This an interpretation might result from the fact that a specified level of treatment is explicitly required by the law with much attention given to improving the quality of the effluent discharge. The focus on treatment before discharging might tend to lessen attention to techniques aimed at prevention, control, and reduction of wastewater, as well as treatment techniques applied in the stream.

An alternative interpretation of eligiblity as defined in the 1972 Act is the following: emphasis on treatment techniques is inherent in the legislation, insofar as goals and requirements are stated in terms for achievement of non-polluting discharges and minimum treatment standards. Similarly, emphasis is on action prior to effluent discharge. Nonetheless, the legislation does not appear to exclude from grant eligibility the nonplant techniques previously mentioned. The exceptions are techniques requiring expenditures for collection systems in new communities, grants implicitly prohibited by Section 211 of the 1972 Act; as well as low-flow augmentation and in-stream aeration.

In conclusion, subject to the noted exceptions, nonplant techniques appear eligible for grants in the 1972 Act. In particular, techniques such as land disposal and community septic tanks, which can provide the equivalent of secondary treatment with no direct discharge into a waterway, satisfy the tenets of the 1972 Act. Techniques which prevent or reduce the generation of wastewater also comply with the law by reducing the discharge of pollutants into waterways. Nonplant treatment techniques, which alone or in combination with other nonplant or plant techniques are able to fulfill water quality standards, likewise are compatible with the law.

Another type of eligibility issue relates to project size. For a given expected growth in demand for waste treatment services, projects having longer design periods imply that higher levels of reserve capacity are needed.

Historically, construction costs for (1) treatment plant projects having a design period of up to 20 years, and (2) interceptors having as long as 50-year design periods, were eligible for a grant award. Evaluation of alternative grant-eligible design periods is presented in Chapter VII.

Grant Percentage

According to Section 202(a) of the 1972 Act, the Federal grant rate is 75 percent of the cost of construction of a treatment works. This appears to be the current legal maximum cost sharing proportion.

One may ask if this is the minimum legal cost-sharing proportion. The response depends upon the definition of "treatment works." Until recently, as reflected in the interim grant program regulations, it was required that a fundable Step 3 project result in an operable treatment works. Thus, under the former interpretation, the legal minimum, as well as maximum Federal cost-sharing proportion was 75 percent of total eligible construction costs of a completed facility.

However, program requirements for a minimum grant of 75 percent of total construction costs were criticized and have since been changed. According to the Senate Committee on Public Works [6], this requirement did not allow a State the flexibility "to use its annual allocation of grant funds among as many projects on its priority list as it wishes, on the basis of what can be accomplished in a given year, rather than to tie up all its funds in a few large projects at the top of a State's priority list." The committee further stated that "phased funding," whereby a portion of a total facility would be approved for a grant would not, under the 1972 Act, commit the grant program to eventual funding of the total facility nor create a pool of reimbursable claims against the grant program for an ultimate grant of 75 percent of the full construction costs of the completed facility.

Section 203 of the 1972 Act has since been interpreted to permit States to divide individual treatment works into separate parts for the purpose of funding. This new interpretation is reflected in the final program regulations which provide for grants of 75 percent of the construction cost of segments of treatment works. "Segment" is defined as "any portion of an operable treatment works" and its completion need not result in an operable treatment works.

In summary, one may conclude that under the present grant program the Federal share must comprise a minimum 75 percent share of the eligible construction costs of an approved project, but that the approved project no longer need result in a completed facility. Alternatives to this program are considered in Chapter VI.

User Fees

With respect to legislative requirements for user fees, Section 204(b)(1)(A) of the 1972 Act states the following:

> "... the Administrator [of EPA] shall not approve any grant for any treatment works ... unless ... the applicant ... has adopted or will adopt a system of charges to assure that each recipient of waste treatment services within the applicant's jurisdiction ..., will pay its proportionate share of the costs of operation and maintenance ..."

In effect, this section provides for collection of user fees to repay O&M expenses from all recipients of services.

Section 204(b)(1)(B) requires that the Administrator shall also have determined that the applicant has done the following:

> "...made provision for the payment to such applicant by the industrial users of the treatment works, [sic] of that portion of the cost of construction of such treatment works (as determined by the Administrator) which is allocable to the treatment of such industrial wastes to the extent attributable to the Federal share of the cost of construction..."

Specifically, fees will be collected from industrial users to pay that portion of the grant amount allocable to treatment of industrial waste. However, industry is not required to pay an interest charge on their portion of the Federal grant.

It is further specified in Section 204(b)(3) that the grantee do the following:

> "... retain an amount of the revenues derived from the payment of costs by industrial users of waste treatment services, to the extent costs are attributable to the Federal share of eligible project costs pursuant to this title as determined by the Administrator, equal to (A) the amount of the non-Federal cost of such project paid by the grantee plus (B) the amount, determined in accordance with regulations promulgated by the Administrator, necessary for future expansion and reconstruction of the project except that such retained amount shall not exceed 50 per centum of such revenues from such project."

In effect, this last section provides that the grant recipient will retain 50 percent of the amount recovered from industrial users against the Federal grant. The 50 percent limit is the effective rule for retention of industrial user fees because the sum of the non-Federal capital cost and the amount necessary for future expansion and reconstruction, under normal circumstances, will exceed 50 percent of the amount recovered from industrial users against the Federal grant.

In consequence of differences in rates of industrial participation among municipal treatment facilities, the retention of one-half of the Federal grant portion applicable to industry is an important determinant of unequal cost-sharing proportions across communities. The impact of industrial participation and cost recovery requirements on municipal and industrial cost shares is quantified in Chapter VIII.

Nonetheless, Federal regulations [1] pursuant to the 1972 Act stipulate that a minimum of 80 percent of the retained amounts, plus appropriate interest, must be set aside in a reserve fund for future expansion and reconstruction. Regulations allow the remaining 20 percent of retained amounts to be allocated by the grantee, upon his own discretion.

The reserve fund may be used only for eligible project costs related to expansion and reconstruction of the original project and only with written approval of the Regional Administrator. The holder of a reserve fund may apply that fund to project costs for which a grant is requested or may use it to pay for project costs apart from any grant request. However, if a grant is forthcoming, it is required that the amount in the reserve fund be deducted first from eligible project costs for the purpose of determining the size of the grant.

Subsequently, Section 35.927-17 of the Grant Program Regulations provides the following:

> "...allowable project costs [are to be] reduced by an amount equal to the unexpended balance of the amounts retained by the applicant for future reconstruction and expansion ... together with interest earned thereon."

Thus, whenever a grant is to be provided, the holder of a reserve fund has no choice but to apply the amount then in the fund to that project, and have the amount of the grant eligible costs thereby reduced; however, he need not have held the fund until a grant is forthcoming.

Future Chapters

This chapter has described some important elements of the current Federal Construction Grant Program. Future chapters will focus in more analytical depth upon several of these program elements.

The structure of an economically desirable cost-sharing program is developed in the next chapter. Afterwards, in light of (1) those findings, (2) constraints inherent in the present program, and (3) second-best considerations, separate chapters are devoted to designing a cost-effective Federal grant program, with specific emphasis upon the grant formula, the allotment formula, reserve capacity and design period limitations, as well as industrial cost-recovery requirements.

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CHAPTER IV

THEORY OF COST SHARING FOR MUNICIPAL WASTEWATER POLLUTION ABATEMENT PROJECTS

During the past 25 years, the Federal government has chosen to "finance" the cost of municipal wastewater pollution control through the process of cost sharing. Also known as matching grants, cost sharing has traditionally involved the subsidization by the Federal government of a predetermined percentage of eligible construction costs.

Cost sharing serves two major functions. First, it reduces the local cost burden of adopting any level of pollution control, when the method of control satisfies the eligibility requirements for the Federal grant. Second, cost sharing serves as an inducement for communities to adopt the level and type of abatement activities that are considered socially desirable.

In reference to the first function of cost sharing, the rationale for the Federal subsidy rests upon issues relating to property rights and equity considerations. Since some pollution control measures are mandatory, it can be argued that the Federal government, as a result of potential infringement of community property rights, should bear some portion of treatment costs. Otherwise, communities may be hard pressed to pay for the required pollution control activities. In addition, benefits from abatement are often wide-spread, extending beyond the local jurisdiction, so that it is not unreasonable for society to pay for these external benefits through Federal cost-sharing subsidies.

The reasoning behind the second function of cost sharing is rooted in the relationship between the Federal subsidy and to the issue of externalities. An external diseconomy exists when party A imposes costs on party B, but these costs are not taken into account by party A.

In the presence of pollution damages imposed on downstream communities, an externality will be generated if inter-community negotiations or government intervention does not take place. In these cases, each community will choose a level of pollution abatement which is locally but not socially optimal. (Throughout the study, "social" refers to the sum of the relevant local and non-local factors.)

The objective of this chapter is to investigate the ability of cost sharing to encourage local communities to make socially desirable abatement decisions. Initially, a brief discussion is provided of alternative pollution control implementation strategies. Afterwards, a detailed study of cost sharing is conducted.

The analysis shows that for reasons discussed later, cost-sharing is not well suited for inducing communities to achieve socially desirable levels of pollution abatement. However, cost sharing is well suited, in conjunction with mandated abatement requirements, to encourage communities to select socially cost-effective pollution control projects. To accomplish this, the government could provide higher Federal cost-sharing rates and relatively larger funding authorizations for those projects which are socially desirable, but which the locality would not ordinarily choose to undertake on its own.

Alternative Implementation Mechanisms

The most common implementation method for inducing pollution control is the regulatory approach in which certain abatement standards are mandated by Federal law. This is the primary policy in the United States as well as in other parts of the world. The regulatory approach for implementing environmental policy has the appearance of being equitable, and is generally favored by governments owing to the belief that it is easier to administer and requires less information than alternative implementation strategies.

A second implementation method involves the use of pollution related effluent charges. A polluter is required to pay a fee to a central authority, the size of the fee being related to the volume and intensity of the effluent. It can be demonstrated that an effluent tax encourages an outcome wherein the resulting level of effluent abatement is achieved at least aggregate abatement cost by the polluters subject to the effluent tax. This outcome is unlikely to occur under a system in which abatement requirements are imposed on individual polluters.

There are additional advantages that derive from use of effluent charges. One which is quite important and often overlooked has been suggested by Tullock [1]. He points out that while ordinary forms of taxes (income, sales, etc.) tend to distort relative prices and hence resource allocation, effluent taxes encourage a more efficient use of resources for controlling pollution and for producing final products. At the same time, effluent taxes result in public revenues. Therefore, effluent taxes generate an "excess benefit", because the revenues collected can be used to replace the proceeds that derive from other forms of resource-distorting taxes.

It has been pointed out by Rose [2] that in the absence of a price for remaining discharges, pollution related products (in this case sewer services) will be underpriced and overproduced. Rose also maintained that even when standards are being met and marginal pollution damages are zero the residual charge serves the important function of allocating the assimilative capacity of the receiving water in an efficient way among dischargers.

For example, suppose that each discharger has an effluent limitation based on a given stream standard. As the number of dischargers increases, the effluent allotment to each will have to decrease. An appropriately set effluent tax would reflect the marginal control costs imposed by each discharger on the others. As a result, those dischargers who could further treat their wastewater at relatively low cost would tend to do so, while those who would incur large incremental treatment costs would choose to pay the effluent tax. Hence, a given level of total effluent would tend to be achieved at minimum aggregate abatement cost.

As indicated previously, there exists the belief on the part of program administrators that the regulatory appraoch is easier to administer, requires less information, and is more equitable than alternative implementation strategies such as effluent charges. Those who have investigated alternative implementation strategies in some detail do not necessarily concur with these conclusions.

A discussion by Kneese and Bower [3], later supplemented by Rose [2], indicates that determination of appropriate effluent standards requires more information about control costs of polluters than is needed to set appropriate effluent charges. This is the case because the regulatory approach requires information specific to each of the individual polluter's cost of control function, while the effluent-charge approach requires information essentially contained in the polluters' aggregate cost of control function.

Preference for the regulatory approach over the effluent-charge approach on the basis of equity considerations appears to be unfounded. A system of uniform or proportional abatement requirements tends to favor the largest communities and the worst polluters, which can hardly be termed equitable. For example, the larger communities generally have the lowest cost per unit of abatement, owing to economies-of-scale, industrial participation, and favorable financing terms. A system of standards generally will fail to take these factors into account, and accordingly will require too little abatement from larger communities and too much abatement from smaller communities.

At the same time, since the standards do not require payment for any remaining discharge, the worst polluters will be allowed to generate the highest levels of uncompensated ecological damages on the receiving waters. In fact, under direct regulation, none of the polluters will be assessed a charge for the pollution damages which they impose on society.

Conversely, an effluent charge system allows each polluter the flexibility to decide how and to what extent to control pollution, depending upon the size of the discharge fee and upon the polluters' costs of controlling pollution. Also, an effluent fee placed on remaining discharge provides that each polluter is treated fairly, in the sense that each pays the same price per unit of discharge.

A frequent criticism of effluent charges is that they are "licenses to pollute." Perhaps so, however the present regulatory system provides a "license" to pollute which is free, as long as the standards are complied with. Even if the standards are not being met, legal and economic penalties often prove ineffective. The effluent charge provides a continuing incentive to seek improved treatment methods (as opposed to legal delays) which achieve discharge reductions in excess of the level implied by a system of standards [4].

Critics of effluent charges occasionally contend that the resulting pollution level is too uncertain in the presence of effluent charges. Nevertheless, the potential adverse effects of such uncertainty could be easily reduced by simply raising the fee per unit of discharge. Alternatively, these effects could be completely eliminated by adopting a system of marketable discharge permits [5].

It is sometimes maintained that a system of effluent charges imposes higher costs on polluters than does a system of standards. However, this depends upon the levels of the standards, the parameters of the effluent charge system, and the polluters' abatement cost functions. Theoretically, an effluent charge system can always be designed which would be less costly even from the polluters' viewpoint than a system of standards. This can be accomplished by returning the effluent charge payments to polluters, with the size of the individual rebates independent of the resulting levels of pollution.

In spite of the foregoing arguments in favor of effluent charges, it should be recognized that in many cases municipalities are presently operating under significant economic hardships. The imposition of effluent charges may contribute to further erosion of a municipality's ability to raise funds needed to provide social services. Also, there are constitutional and political constraints which currently prevent imposition of Federal effluent charges on municipalities.

Subsidies are the third implementation mechanism for encouraging socially desirable municipal pollution control actions. A subsidy program may take several forms. However, in practice, subsidy programs for municipalities have traditionally been limited to the cost sharing of grant-eligible abatement expenses.

By focussing upon subsidizing selected inputs, such as capital resources, existing cost-sharing programs tend to bias local project selection towards the use of those techniques and factor inputs which have the highest Federal cost-sharing proportions. As we shall see, even if Federal grants were not biased towards specific cost categories, communities may respond to cost sharing by selecting projects that are locally but not necessarily socially desirable.

Nevertheless, despite these inherent shortcomings, the current municipal wastewater Construction Grant Program is of a cost-sharing nature. Thus, the remainder of this chapter investigates the theoretical foundations of cost-effective municipal subsidy programs that can be classified under the cost-sharing rubric; and examines the efficacy of cost-sharing as an instrument for inducing communities to adopt the socially desirable levels of pollution control.

Summary of Findings

In the present municipal wastewater Construction Grant Program, a single Federal cost-sharing rate of 75 percent is applicable to the capital costs of eligible construction projects. This rate applies uniformly across different communities and alternative grant-eligible construction projects.

The present Construction Grant Program also requires that minimum Federally mandated levels of wastewater treatment be achieved by grantees. Thus, grant-recipient communities are not free to choose a level of wastewater pollution control below the minimum level allowed.

An additional element of the present program is the manner in which Federal grant funds are allotted to the States. Although distribution of grant funds within a State to wastewater treatment projects is supposed to be made on a cost-effective basis, this is not the case for distribution of limited Federal grant funds among the States.

The grant program also stipulates that communities are required to recover from industry the portion of the Federal grant applicable to industrial use of municipal facilities. One-half of this recovered amount is retained by the communities and the remainder is returned to the U. S. Treasury. Thus, even though the nominal Federal capital grant rate is equal among communities, the effective "project" grant rate will differ, depending essentially upon the relative degree of industrial participation and the ratio of grant-eligible capital costs to total project costs (capital, land, operation and maintenance).

In addition, given any proportion of wastewater treatment costs borne by the Federal government (i.e., the cost-sharing proportion), communities may be limited by their local budget or by political and legal factors from choosing the socially desirable levels of abatement.

Under these conditions, there is sufficient justification for concluding that abatement resources will not be allocated to pollution control projects such that the difference between social abatement benefits and costs is maximized. Moreover, the resource costs required to generate the resulting level of social and local abatement benefits will not be minimized, i.e., abatement resources will not be efficiently allocated.

Each element of the Construction Grant Program discussed above contributes to this economically inefficient outcome. Nevertheless, an important question is: Under the most favorable conditions, is it generally possible to achieve an efficient allocation of abatement resources with a Federal cost-sharing program ?

To answer this question, a model is designed which removes the obstacles to an efficient allocation of abatement resources inherent in the present Construction Grant Program. In this model, construction grants are replaced by project grants, applicable to total costs, in order to eliminate the local bias to prefer capital intensive projects. More importantly, the project grant rate is allowed to vary by community and may be set by the grantor at a rate consistent with achieving a socially desirable level of abatement.

In addition to these important departures from the present program, direct Federal grants to projects are assumed to replace the allotment of Federal grant funds to the States, and the relationship between units of pollution abatement and the resulting dollar value of abatement benefits is assumed to be known. Also, the model assumes the absence of (1) Federally mandated levels of treatment and (2) local funding constraints for abatement activities.

The results generated by the model show that variable cost-sharing proportions can be found which will encourage a socially optimal allocation of abatement resources, if sufficient Federal funds are available to subsidize the appropriate amount of abatement resources requested by each of the individual communities at the optimal cost-sharing rates. 1/

When cost-sharing funds are constrained, so that the socially optimal abatement resource levels cannot be Federally funded in all communities, it is obviously not possible to induce on optimal allocation of abatement resources with a cost-sharing program as defined herein. More surprisingly, there also does not exist a set of cost-sharing rates which will generate an efficient allocation of abatement resources. In other words, the real resource cost of achieving any level of pollution control will not be minimized.

The reason for this inefficiency is that not only are Federal funds constrained, but the cost-sharing rates apply to the total costs of controlling pollution and not simply to incremental costs. Thus, in order to induce higher levels of clean-up, higher cost-sharing proportions must be provided for both existing as well as for incremental abatement costs.

1/ While the current Construction Grant Program also induces variable cost-sharing rates among communities, these rates bear no obvious relation to the achievement of an economically efficient (or equitable) abatement solution.

This inherent inflexibility of cost sharing, in the presence of a Federal funding constraint, means that resources cannot be easily rearranged at the margin to encourage an efficient solution. That is, although the incremental resource costs of small changes in abatement may also be small, the Federal costs of these small changes are relatively high. This "lumpiness" of Federal costs will ensure that the benefits obtained under a constrained cost-sharing program could have been secured at lower resource cost either by direct enforcement or through alternative abatement incentive programs such as effluent charges.

Of course, the situation deteriorates considerably when the idealistic assumptions described previously are relaxed, and some real-world conditions which are not incorporated in the model are taken into account. Thus, while traditional cost-sharing programs provide some incentive for communities to undertake additional abatement, they are not "efficient" mechanisms for doing so.

Despite their shortcomings as a means for inducing appropriate levels of abatement, cost-sharing programs can be designed to encourage communities to undertake socially cost-effective abatement activities. These activities include the proper mode of treatment and collection of wastewater; utilization of the appropriate level and mix of resource inputs for the mode selected; provision for sufficient but not excessive reserve capacity; and maintenance of the performance integrity of the pollution abatement system. Chapters V through VIII are concerned with the specific elements of a cost-sharing program which will achieve these pollution control objectives.

Background

The Federal Water Pollution Control Act Amendments of 1972 authorize the Administrator of the Environmental Protection Agency to make grants for the construction of publicly owned waste treatment works. Those projects selected for an award are provided with a Federal grant equal to 75 percent of eligible construction costs.

Federal cost-sharing programs such as this one have been criticized previously in the literature. For example, Fox and Herfindahl [6] argued that there exists a tendency to encourage the overbuilding of wastewater treatment facilities because, inter alia, the beneficiaries of the projects usually bear a relatively small portion of construction costs.

Regan [7] recognized that the attainment of an efficient allocation of resources was sensitive to cost-sharing arrangements. However, his prescription that "... it would seem necessary to provide that marginal benefits from each purpose accruing to each participant be sufficient to cover the corresponding marginal costs borne by each" is not particularly helpful, since each participant can be expected to attain this position on their own, with or without cost sharing.

Loughlin [8] suggested that different cost sharing policies within and among various Federal agencies lead to inefficient project choices with regard to techniques, scale, and utilization. A recent study by the National Water Commission [9] has found that existing cost-sharing arrangements encourage the adoption of control methods which may be cost-effective for the local community, but which are not the least-costly solutions for society.

Formalization of the relationship between cost sharing and economic efficiency when third-party effects are generated was first undertaken by Marshall [10, 11]. In these studies, Marshall considered the design of cost-sharing rules which would induce communities to choose levels of pollution abatement that are socially optimal.

In the presence of external effects and in the absence of Federal government (grantor) intervention, Marshall showed that the local community would not adopt the socially optimal abatement level. However, Marshall argued that this optimal level could be encouraged by setting the cost-sharing rate such that the ratio of local to social costs is equal, at the margin, to the ratio of local to social benefits at the margin. "Social" refers to the sum of local and non-local factors. This cost-sharing rule, that is, where costs are shared in proportion to benefits at the margin, was called the Association Rule by Marshall. (Note that the optimal grant rate applies to all relevant abatment costs and may vary across communities. This concept is quite different from the uniform rate applicable only to construction costs which exists in the present Federal wastewater grant program.)

In order to apply this rule, the socially optimal level of abatement is ordinarily determined first. Then the ratio of local to social benefits at the margin is calculated. Finally, the grantor cost-sharing proportion is set equal to one minus this marginal benefit ratio. If the ratio of marginal local to marginal social benefits is constant at all relevant levels of abatement, the appropriate grantor cost-sharing proportion can be calculated directly from the marginal benefit ratio, without first computing the optimal level of abatement.

Application of the Association Rule to optimize resource allocation for pollution control is critically dependent upon the satisfaction of several assumptions not made explicit by Marshall. One of the most important implicit assumptions is that sufficient funding is available to pay the federal government's share of costs at the socially optimal abatement levels.

The model developed in the next section allows for relaxation of this assumption. When Federal cost-sharing funds are constrained, two important conclusions emerge.

First, in these cases there are no simple (i.e., independent) cost-sharing rules that can be specified to allocate the available grantor funds among communities in a manner that will maximize the difference between social abatement benefits and social abatement costs, subject to the cost-sharing constraint. Thus, the constrained optimal levels of abatement (and hence the appropriate cost-sharing proportions) have to be simultaneously determined for all relevant communities.

Second, due to the inherent inflexibility of cost sharing as a pollution abatement incentive mechanism, those cost-sharing proportions which do maximize the difference between social abatement benefits and social abatement costs, subject to the Federal funding constraint, generally do not also ensure that social abatement benefits associated with the resulting level of abatement costs are maximized. That is, even after application of and response to the constrained optimal cost-sharing proportions, a reallocation of the abatement resources among projects could increase social abatement benefits without increasing abatement costs. However, to do so would result in a violation of the constraint on available grant funds.

Cost-Sharing Model 2/

The objective is to determine the set of cost-sharing proportions that will maximize the difference between the benefits and costs of abatement across communities. The cost-sharing proportions can vary among communities and they apply to all relevant abatement cost categories.

2/ Portions of this section were recently published in Land Economics, Volume 52, No. 4, November, 1976, by Marshall Rose, under the title "A Note on Cost Sharing of Municipal Wastewater Pollution Abatement Projects," pp. 554-558.

The approach developed herein can also be applied to the case in which only designated capital costs are eligible to receive a Federal grant. The abatement cost functions would then be separated into two parts, denoted by grant-eligible and grant-ineligible costs. Equivalently, the benefit functions could be redefined as being benefits net of grant-ineligible costs. Subsequently, the analysis would coincide with the approach taken in the remainder of this section for cases in which all abatement costs are eligible for a Federal grant.

Implicit in the analysis to follow is the assumption that each community has only a single feasible abatement project. Alternatively, we could assume that if the community has to choose among more than one wastewater treatment project, differentiated perhaps by project location, then each alternative has equivalent total and local benefit functions, expressed in terms of units of abatement. As a result, local choice of the most appropriate project will coincide with the socially preferred project. Complications which can arise when this assumption is not satisfied are considered in the penultimate section of this chapter.

Several terms require careful definition. Net social abatement benefits refers to the difference between societal benefits and costs that derive from a given level of pollution abatement. A socially optimal allocation of abatement resources occurs when the level of pollution control adopted among communities (projects) maximizes net social abatement benefits. An allocation of abatement resources is said to result in a constrained optimal solution if net social benefits are maximized subject to the Federal cost-sharing constraint. Finally, abatement resources are efficiently allocated if net social benefits cannot be increased by reallocating the existing level of abatment resources among projects. Equivalently, an efficient allocation implies that the resulting level of social abatement benefits is achieved at least social cost.

An optimal allocation of resources clearly must also be an efficient allocation. However, a constrained optimal allocation of abatement resources need not be an efficient allocation.

The following assumptions are made:

1. Abatement cost and benefit functions are independent among communities under consideration for cost-sharing funds.

2. Costs, benefits, and available Federal grant funds are expressed in equivalent dollar terms, either on an annualized or present value basis.

3. Abatement costs are defined to include all costs associated with abatement, e.g., capital, operating and maintenance, land acquisition, etc. All abatement costs are eligible for a Federal grant.

4. Abatement costs are a continuous function of abatement units, and approach zero as the level of abatement approaches zero. In other words, the resources required to achieve any level of abatement are perfectly divisible. Otherwise, a community may prefer a zero level of abatement if the resources associated with initial levels of abatement are not perfectly divisible. In these cases, there may be no cost-sharing rate (uniformly applied at any level of cost) which will satisfy both total and marginal conditions for inducing the socially desirable level of abatement.

5. Abatement benefit and cost functions possess continuous first- and second-order derivatives.

6. Marginal abatement benefits are a constant or a monotonically decreasing function of abatement units for the given size of the waste load influent to be treated).

7. The size of the local pollution waste load influent is independent of the Federal cost-sharing rate.

8. Local pollution control decisions take into account the abatement costs borne by all users of the public facility.

9. No negotiations take place between polluters (grantees) and recipients of pollution, and Federally mandated abatement requirements are absent.

10. Federal grant funds may be distributed periodically or at one time. In the former case, Federal funding must be provided to the entire set of relevant grant recipients, at the appropriate cost-sharing proportions, each time Federal payments are forthcoming. Thus, grant recipients are funded in parallel rather than sequential fashion, and analytical complications caused by inter-temporal distribution of grant funds can be safely ignored.

11. Each community's abatement objective is to maximize net local abatement benefits.

The following symbols are defined for each of the i = 1, 2, ..., m communities:

Q_i = units of pollution abatement.

$B_i(Q_i)$ = social benefits (dollar value) resulting from local abatement.

$b_i(Q_i)$ = abatement benefits accruing to the local community.

$C_i(Q_i)$ = social costs of local abatement.

ϕ_i = local cost-sharing proportion, i.e., the fraction of social abatement costs to be borne by the local community.

$c_i(Q_i)$ = local costs of abatement, equal to social abatement costs multiplied by the local cost-sharing proportion.

S = amount of available Federal cost-sharing funds.

We first determine the appropriate cost-sharing proportions when sufficient Federal funding is available to pay for the socially optimal treatment levels. Marshall [10] solved an equivalent problem using a different approach than is presented here.

The socially optimal abatement levels, $Q_i = Q_i^*$, occur at the point where social marginal abatement costs equal social marginal abatement benefits:

$$\frac{dC_i}{dQ_i} = \frac{dB_i}{dQ_i}. \qquad (1)$$

From the definitions of social and local abatement costs, we can write

$$\frac{dc_i}{dQ_i} = \frac{dC_i}{dQ_i}\phi_i. \qquad (2)$$

Each community will abate up to the point at which local marginal costs are equal to local marginal benefits. Accordingly, using the expression for local marginal costs given in equation (2), we can express a community's abatement response in the presence of cost sharing as follows:

$$\frac{dC_i}{dQ_i}\phi_i = \frac{db_i}{dQ_i}. \qquad (3)$$

Thus, the level of local abatement associated with any ϕ_i is found by solving equation (3) for Q_i:

$$\phi_i = \frac{\frac{db_i}{dQ_i}}{\frac{dC_i}{dQ_i}}. \qquad (4)$$

At $Q_i = Q_i{*}$ the denominator of equation (4) can be replaced by equation (1). Substituting $Q_i{*}$ for Q_i in equation (4), the optimal cost-sharing proportions, $\phi_i{*}$, can be expressed by

$$\phi_i{*} = \frac{\dfrac{db_i(Q_i{*})}{dQ_i}}{\dfrac{dB_i(Q_i{*})}{dQ_i}} . \tag{5}$$

Of course, it then follows from equations (2) and (5) that for $\phi_i = \phi_i{*}$, local marginal costs equal local marginal benefits at $Q_i = Q_i{*}$:

$$\frac{dc_i(Q_i{*})}{dQ_i} = \frac{db_i(Q_i{*})}{dQ_i} .$$

Thus, by setting ϕ_i equal to the ratio of local to social marginal abatement benefits at $Q_i{*}$, each community will be induced, through cost sharing, to adopt that level of abatement which is optimal for society as well as themselves.

We now turn to the case in which there is a constraint on available Federal cost-sharing funds. (Sufficient local funds are, however, assumed to be available to pay for the constrained optimal levels of abatement). The amount of constrained Federal funds, S, is assumed to be less than S*, the amount needed by the Federal government to pay for the socially optimal levels of abatement.

We want to determine the appropriate cost-sharing proportions which will maximize net social benefits across all communities, subject to the Federal cost-sharing constraint, S. As previously demonstrated, it is necessary to solve first for the constrained optimal levels of abatement, Q_i^s, before the constrained optimal cost-sharing proportions, ϕ_i^s, can be found.

The expression to be maximized is

$$\sum_{i=1}^{m} \left\{ B_i(Q_i) - C_i(Q_i) \right\}. \tag{6}$$

The Federal funding constraint can be expressed by

$$S = \sum_{i=1}^{m} (1 - \phi_i) \; C_i(Q_i). \tag{7}$$

To find the Q_i's, the Lagrangian function H is formed from equations (6) and (7):

$$H = \sum_{i=1}^{m} \left\{ B_i(Q_i) - C_i(Q_i) \right\} + \lambda \left\{ S - \sum_{i=1}^{m} (1 - \phi_i) \; C_i(Q_i) \right\},$$

where λ is the Lagrangian multiplier.

The local abatement response to any cost-sharing proportion is given in equation (4). Therefore, since ϕ_i can be expressed in terms of Q_i, and since we are trying to find the constrained optimal Q_i, it is convenient now to substitute equation (4) into the expression representing H.

At this point each of the partial derivatives of H with respect to the Q_i, as well as the partial derivative of H with respect to λ, are set equal to zero. Solving these m + 1 equations yields the values for the Q_i's. Replacing these abatement levels into m equations given by (4), we obtain the ϕ_i's.

In general terms, the first-order condition for the constrained optimal solution is found by selecting any two of the first m equations generated by setting the partial derivatives of H with respect to the Q_i equal to zero. Solving these two equations simultaneously, the following first-order condition is obtained, for communities j and k:

$$\left(\frac{\dfrac{dB_j}{dQ_j} - \dfrac{dC_j}{dQ_j}}{\dfrac{dC_j}{dQ_j}} \right) \left\{ \frac{\zeta_j}{\gamma_j} \right\} = \left(\frac{\dfrac{dB_k}{dQ_k} - \dfrac{dC_k}{dQ_k}}{\dfrac{dC_k}{dQ_k}} \right) \left\{ \frac{\zeta_k}{\gamma_k} \right\} \tag{8}$$

for $j \neq k$, and where

$$\zeta_i = \left\{ \frac{dC_i}{dQ_i} \right\}^3$$

$$\gamma_i = -\left\{ \frac{dC_i}{dQ_i} \right\}^3 + C_i(Q_i) \left\{ \frac{d^2 b_i}{dQ_i^2} \frac{dC_i}{dQ_i} - \frac{db_i}{dQ_i} \frac{d^2 C_i}{dQ_i^2} \right\} + \frac{db_i}{dQ_i} \left\{ \frac{dC_i}{dQ_i} \right\}^2 .$$

Condition (8) indicates that attainment of the constrained socially optimal abatement levels ordinarily does not result in an efficient allocation of abatement resources. This contention can be proved easily by showing that an efficient allocation of abatement resources occurs when the ratio of net marginal social benefits to marginal social costs is equalized among communities. This requirement is equivalent to a first-order condition similar to (8), but without the terms denoted by ζ_i / γ_i .

Condition (8) and the first-order condition necessary for an efficient allocation of abatement resources will only coincide in two instances: first, when the ζ_i / γ_i are equal among all communities, that is essentially when all communities have exactly the same cost and benefit functions; second, when marginal social benefits equal marginal social costs for each community, in other words, when the unconstrained socially optimal abatement level is attainable with the available Federal cost-sharing funds. In all other instances, an efficient allocation of abatement resources will not be achieved, despite the fact that net social benefits have been maximized subject to the Federal cost-sharing constraint.

This inefficient result is due to both the constraint on Federal funds, as well as to the stipulation that cost-sharing rates apply in total, and not simply at the margin. Thus, additional abatement must be induced by higher cost-sharing proportions for total costs, and not simply for incremental costs. As a consequence, Federal cost-sharing funds cannot be easily fine-tuned since relatively large changes in Federal funds are needed to induce relatively small changes in resource expenditures. This inherent inflexibility, or "lumpiness" in Federal cost shares generally ensures that abatement resources cannot be rearranged at the margin to achieve an efficient solution.

Furthermore, because it is not possible to determine the constrained optimal abatement levels independently among communities, there is no simple cost-sharing rule that can be separately applied to each project. Of course, this conclusion is also valid when the ratio of local to social marginal benefits is constant for each community at all levels of abatement.

Comparison of conditions (5) and (8) yields several interesting observations. It is clear from (5) that when sufficient Federal funds are available to pay for the optimal abatement levels, a decrease in the ratio of local to social marginal benefits for a particular community results in an increase in the Federal cost-sharing proportion to that community.

Consider the constrained funding case. Suppose there are two communities, j and k, with identical cost and benefit functions, except that the social marginal benefit function, at all levels of abatement, is greater for j than for k. Satisfaction of condition (8) requires that abatement in j be increased relative to k. To encourage this result, j must therefore have a higher Federal cost-sharing proportion than k. However, further meaningful generalizations concerning relative cost-sharing proportions, as a result of variations in the ratio of local to social marginal benefits among the two communities, cannot be made.

Numerical Calculations

This section demonstrates the preceding results by presenting some numerical examples. The initial calculations relate to the case of cost sharing between two communities. Subsequently, a cost-sharing problem associated with mutually exclusive abatement project alternatives within a community is considered.

$$B_1(Q_1) = 10Q_1$$

$$b_1(Q_1) = 5Q_1$$

$$B_2(Q_2) = 20Q_2$$

$$b_2(Q_2) = 16Q_2$$

$$C_1(Q_1) = Q_1^2$$

$$C_2(Q_2) = 2Q_2^2$$

The objective is to find those cost-sharing proportions for the two communities which will maximize net social benefits subject to the Federal cost-sharing constraint. Substituting the given abatement cost and benefit functions into condition (8), we find that

$$Q_1 = 1.25\ (Q_2 - 1). \qquad (9)$$

The constraint equation is found from (7) to be

$$S = -2.5Q_1 + Q_1^2 - 8Q_2 + 20Q_2^2. \qquad (10)$$

The constrained optimal abatement levels for the two communities, Q_1^s and Q_2^s , and the constrained optimal grantor cost-sharing proportions, $1 - \phi_i^s$, $i = 1, 2$, can be calculated for different values of $S \leqq S^*$ from equations (9) and (10). The results are presented in Table IV-1 for several cases.

In the first case the available Federal cost-sharing funds are not constrained. From equations (1) and (4), the optimal grantor cost-sharing proportions are found to be 0.5 and 0.2 for communities 1 and 2, respectively. This subsidy policy induces abatement of 5.00 units from each community, requiring use of social resources costing \$25.00 in the first community and \$50.00 in the second. The grantor cost share is simply \$25.00 (0.5) + \$50.00 (0.2) = \$22.50. The same result is obtained by employing equation (8) plus the constraint equation (7), with S = \$22.50.

In Case 2 less Federal funds are available than are needed to generate the unconstrained socially optimal solution. The results clearly show that maximization of net social benefits subject to the cost-sharing constraint may not result in an efficient allocation of abatement resources.

When S = \$7.68, the constrained optimal levels of abatement are found to be $Q_1^s = 4.00$ and $Q_2^s = 4.20$. These abatement levels require social resource expenditures amounting to \$51.28, and generate social benefits worth \$124.00. However, if the abatement levels were 4.135 units in both communities, social benefits would be \$124.05, while social resource costs would remain unchanged at \$51.28. This latter result is an efficient solution, but it requires a Federal subsidy of \$7.88, which exceeds the \$7.68 that is available in Case 2.

Obviously, if the cost-sharing constraint were \$7.88, a constrained maximization of net social benefits would not ordinarily be achieved by maintaining social abatement resource expenditures at \$51.28. A higher level of resource utilization would be preferable, which would generate net social benefits in excess of \$124.05. However, once again, this new allocation of resources would not be efficient.

Table IV-1

Results of Constrained Cost-Sharing Examples

Case	S	Q_1^s	Q_2^s	$1 - \phi_1^s$	$1 - \phi_2^s$	$\sum B_1(Q_1^s)$	$\sum C_1(Q_1^s)$
1	$22.50	5.00	5.00	0.500	0.200	$150.00	$75.00
2	7.68	4.00	4.20	0.375	0.048	124.00	51.28
3	3.31	3.64	3.90	0.310	-0.026	114.40	43.67
3a	3.31	3.46	4.00	0.277	0.000	114.55	43.94

Abatement units and dollar amounts are rounded to nearest 0.01.
Cost-sharing proportions are rounded to nearest 0.001.

Case 3, in which S = \$3.31, indicates that a negative subsidy, i.e., a tax, is desirable for the second community, and the tax proceeds are used along with available grantor funds to increase the subsidy for the first community. In Case 3a, negative subsidies are not allowed: $1 - \phi_2^s$ is therefore set equal to zero, and equation (7) is solved for Q_1^s. After ensuring that $Q_1^s \leqq Q_1^*$, the Federal cost-sharing proportion is calculated by first substituting $Q_1^s = 3.46$ into equation (4). We then find that $1 - \phi_1^s = 0.277$.

The cost-sharing program studied in this chapter allows for variable cost-sharing rates among communities. It has been assumed that only one relevant abatement project exists within each community. Hence, the appropriate cost-sharing rates have been calculated on the basis of abatement induced for the single community project.

In some cases, however, a community may have to choose among several projects which are mutually exclusive. The most obvious example of this occurs when the alternatives differ by project location.

Even if cost-sharing rates are allowed to vary by project alternatives, there will not exist sufficient degrees of freedom to ensure the satisfaction of two objectives within a community: namely, attainment of the appropriate level of abatement for the project which is chosen, as well as selection of the project which is socially more desirable. For example, in our model the cost-sharing rates that induce satisfactory levels of abatement for a given project are determined by considering marginal costs and benefits. However, local project selection will be made on the basis of total costs and benefits for each project. Accordingly, there is no reason why the stipulated cost-rates should necessarily ensure that the abatement project which is socially more desirable will in fact generate the highest level of net local benefits and, hence, be selected by the community.

This problem arises in both the constrained as well as unconstrained scenarios. An illustration using a numerical example follows, assuming that Federal cost-sharing funds are unconstrained. Suppose that two alternative locations are available for a given project within a community. Also, suppose that the relevant benefit and cost functions for each project location are given by those expressions used in the previous examples of this section, with one exception. Let

$$C_2(Q_2) = 5Q_2^2.$$

It is simple to show that in the unconstrained Federal funding case, $Q_1* = 5.00$, $1 - \phi_1* = 0.500$; and $Q_2* = 2.00$, $1 - \phi_2* = 0.200$. Net local benefits are $12.50 for the first location, and $16.00 for the second location. Net social benefits are $25.00 for the first location and $20.00 for the second location. Hence, although the second location is socially more desirable, the community will select the first location because it generates higher net local benefits.

Conclusions

This chapter has shown that a cost-sharing program can induce an optimal allocation of abatement resources only under the most favorable and idealistic conditions. One of these conditions is that the program have the flexibility to allow for variable cost-sharing rates. Another important condition is that sufficient Federal funds will be available to pay for the government's share of treatment costs. When this condition is not satisfied, it was demonstrated that those cost-sharing proportions which maximize net social abatement benefits do not ordinarily induce an efficient allocation of abatement resources. This means that the resulting level of social benefits from abatement will not be achieved at minimum social abatement costs.

It was also shown that when a community has to choose among several mutually exclusive abatement projects, cost sharing (limited to a constant rate within each project) cannot simultaneously induce the community to choose the socially desirable level of abatement, as well as the socially desirable abatement project. This particular problem arises in both the constrained and unconstrained Federal cost-sharing cases.

Despite these shortcomings, it is reasonable to suppose that cost sharing can be used as a means for encouraging the selection of certain categories of socially desirable pollution control projects. These projects are those which would not be undertaken by communities to the appropriate extent (1) in the absence of Federal funding, or (2) if Federal funding was forthcoming, but only in the form of uniform cost-sharing rates among projects.

For example, wastewater treatment projects can be expected to result in a substantial proportion of benefits accruing to residents living outside the local community. Wastewater collection projects, such as sewer systems, generate benefits which are captured to a greater extent by local residents. Thus, in the absence of Federal funding or in the presence of uniform cost-sharing rates, we would expect communities to provide too little resources for treatment plants and too much for sewer systems. In order to offset this tendency, it appears desirable to provide higher cost-sharing rates and proportionately larger funding authorizations for wastewater treatment types of projects.

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CHAPTER V

DESIGNING COST-EFFECTIVE FEDERAL WASTEWATER GRANT PROGRAMS FOR MUNICIPALITIES

Chapter IV showed how to determine the economically appropriate Federal grant rate for community pollution abatement projects. It was indicated that there are significant differences between the theoretically optimal cost-sharing system and the present Construction Grant Program. In fact, data currently do not exist which would even allow the theoretically optimal solution to be estimated.

The previous chapter concluded that cost sharing should be used by the Federal government to encourage communities to undertake socially cost-effective abatement projects. Accordingly, the objective of the present chapter is to determine the most important obstacles inherent in the Construction Grant Program to achieving this goal, and then to design grant programs which will mitigate these obstacles. Grant programs considered as substitutes for the existing program are project grants based on both capital and operating costs; and modified construction grants which involve changes in the existing grant rate and grant eligibility. Programs considered as complements to the existing grant program are performance subsidies based on the undertaking of designated treatment activities by the municipalities; and output subsidies based on achieved levels of abatement.

Existing Cost-Sharing Biases in Project Selection

Under the present Construction Grant Program, certain elements of treatment costs, such as operation and maintenance (O&M), and land acquisitions, are not eligible for Federal cost-sharing. In addition, certain types of abatement techniques, such as in-stream aeration and low-flow augmentation, are not eligible for a Federal grant.

As a result of these restrictions, communities may be "financially biased" towards choosing a mode of treatment which achieves Federal standards at least cost to themselves, but which is not the least costly alternative to society. The extent to which one project can be more costly, in real resource terms, than another, and still remain the least costly local option, depends upon the local cost-sharing proportions relevant to each of the alternatives.

The local cost-sharing proportion, denoted by ϕ_v for project v, is equal to the ratio of local to total (social) project costs. 1/ Suppose that ϕ_v is constant for any level of a project's total costs. Consider two projects, where $\phi_2 > \phi_1$. The "maximum potential bias" inherent in the first project is given by the ratio of ϕ_2 to ϕ_1. This ratio indicates the maximum amount by which the cost of the first project can exceed the cost of the second project, while this first project continues to remain less costly to the community than the second.

To demonstrate this concept, an actual case study is used. Three alternative projects for the Cleveland-Akron area were considered by Raymond [1]. Each project was designed to meet identical standards as specified in the 1972 Act, but differed in total costs, as well as in their relative proportion of capital, O&M, and land costs. The data are presented in Table V-1.

Technique 1 is the most costly method to society, requiring annualized costs of $183,200. However, owing to its substantially higher fraction of grant-eligible costs, this technique is the least costly local alternative.

Compared to Technique 3 (the least costly social option), the excess social costs incurred from choosing Technique 1 are equal to $38,600, which is 27 percent higher than the social costs incurred by Technique 3. Further, the size of the Federal cost-share for Technique 1 is 2.37 times the Federal cost share for Technique 3.

The maximum potential bias inherent in Technique 1 can be found by dividing $\phi_3 = 0.74$ by $\phi_1 = 0.51$, which yields a ratio of 1.45. This means that Technique 1 could be as much as 1.45 times, or $65,070 more costly than Technique 3, yet it would continue to remain the minimum local-cost option.

There is additional empirical evidence of project selection bias. In the 1973 Survey of Needs, Category V (the construction costs of correcting combined sewer overflows during the period 1973-1990), was estimated to be $10.8 billion. Using the same time frame as well as the same 1973 price level, the 1974 Needs Survey estimates this category of costs to be $26.1 billion.

1/ Because we have previously used the term ϕ_i to denote the local cost-sharing proportion for community i, the expression for the local cost-sharing proportion of project v in community i should be denoted by ϕ_{iv}. However, since we are concerned here with abatement projects within any one community, we can omit the subscript i in this discussion.

Table V-1

Costs of Wastewater Treatment Alternatives:
Cleveland-Akron Area

	Annual Cost to Society			Federal Cost-Sharing Proportion		Annual Cost To the Local Community			Local Project Cost-Sharing Proportion
Technique	**Construction**	**O & M**	**Total**	**Construction**	**O & M**	**Construction**	**O & M**	**Total**	
1. Land Treatment	$120,900	$62,300	$183,200	75%	0%	$30,225	$62,300	$ 92,525	51 %
2. Plant (Advanced Biological Treatment)	$ 64,200	$84,300	$148,500	75%	0%	$16,050	$84,300	$100,350	68 %
3. Plant (Physical Chemical)	$ 50,500	$94,100	$144,600	75%	0%	$12,625	$94,100	$106,725	74 %

Source: Raymond [1].

The main difference between the two surveys was that unlike the earlier study, the 1974 Needs Survey did not require that project selection for Category V needs "be based on evaluation of the most economical and/or effective alternative" [2]. A substantial portion of the 142 percent cost increase evident in the later survey can probably be explained by the inclusion of costs that were not allowed in the earlier survey owing to the absence of cost-effective analysis. Nevertheless, some portion of the cost increase may be due to the financial bias existing in the Construction Grant Program.

Further empircal evidence of financial bias has been recently presented by the Energy Resources Company [3]. Their analysis indicated that, for the type and location of municipal treatment plants considered, the marginal productivity of capital was less than the marginal productivity of O&M resources, where both measures were expressed in terms of dollars per unit of treated flow.

It is possible that this result is due, in part, to the capital bias inherent in past and existing Federal grant programs. If this is so, then some substitution of O&M for capital dollars would increase treatment efficiency without increasing resource costs. However, since capital resources may be subsidized while O&M resources are not, such a substitution could increase local treatment costs.

Reduction in Project Selection Bias

This section considers ways in which the existing Construction Grant Program could be modified in order to mitigate the tendency for communities to select abatement projects that are overcapitalized from a social viewpoint. Prior to this discussion, two forms of overcapitalization are distinguished.

First, overcapitalization occurs when treatment plants are built larger than is socially desirable. While the locality generally bears only a small proportion of the construction costs needed to provide excess capacity, the resulting level of local benefits that derive from having excess capacity may be substantial. The benefits which the community may capture include (1) the profits that can be generated from servicing industry, (2) the use of excess capacity as a mechanism for encouraging growth and for providing a safety margin for unexpected demand, and (3) the reduced impact on local costs if the Federal grant program is eliminated in the future.

There are basically three policy variables which induce the construction of oversized facilities. The first is Federal cost-sharing proportions that are too high. This issue is discussed briefly in the present chapter. The two other factors are existing grant-eligible design periods and industrial cost recovery provisions. These elements of the Construction Grant Program are studied in subsequent chapters.

The second form of overcapitalization occurs when too much capital resources and too little operating resources are provided for the given level of influent to be treated. In these cases, the total costs of achieving the resulting pollutant removal levels will not be minimized. The main cause of this form of overcapitalization is unequal cost-sharing proportions among cost categories and treatment techniques. The primary concern of this chapter is to consider ways of mitigating this second form of overcapitalization.

Initially, two categories of programs are considered which would substitute for the present grant program. Subsequently, two additional program categories are considered as complements to the existing grant program.

Abatement Project Grants: One method for encouraging local selection of the least-costly projects for achieving mandated levels of pollution control is to provide equivalent cost-sharing proportions. That is, abatement alternatives that have similar purposes (such as the treatment of wastewater) would receive a Federal grant that applies to both construction and O&M costs at the same rate. 2/ By equalizing the Federal grant rate across cost categories and among abatement projects having similar objectives, the community would be encouraged through cost sharing to choose the least-costly project required to achieve a mandated level of pollution control, independent of the absolute size of the abatement project grant rate.

It is instructive at this point to determine the uniform abatement-project grant rate which would allow an equivalent number of construction projects to receive a Federal grant as is possible with the current 75 percent Construction Grant Program. The following assumptions are made:

1. There exists an annual level of authorized project grant funds, denoted by A, and equal to the amount authorized for the current Construction Grant Program.
2. "Authorizations" are synonymous here with Federal funds available to be allocated to the States for project grants.

2/ Conceptually, all categories of abatement costs for designated types of projects should be subject to the same grant rate, in order to induce the selection of the least costly alternatives.

3. Both capital and O&M project grant funds must be drawn from authorized grant funds, A.

4. The Federal project grant rate is denoted by $1-\phi$. Annual grant-eligible O&M costs are denoted by L.

5. Grant-eligible capital costs subject to receiving a Federal grant are denoted by $\tilde{K}$. That is, $\tilde{K}$ is the amount of capital costs generated by Federal authorizations devoted to funding capital resources.

In the present 75 percent Construction Grant Program, the relationship between A and $\tilde{K}$ is given by

$$A = 0.75\tilde{K}. \tag{1}$$

In a project grant program, an amount of grant-eligible O&M costs equal to L would be subject to a Federal grant at rate $1-\phi$. Accordingly, we can write

$$A = (1-\phi)(L+\tilde{K}). \tag{2}$$

Equalizing the number of construction projects funded in each program is equivalent to specifying that $\tilde{K}$ is equal in equations (1) and (2). Solving for $\tilde{K}$ in (1), substituting this expression into (2), and rearranging terms, we find that

$$1 - \phi = \frac{3A}{4A + 3L}. \tag{3}$$

The solution of equation (3) for nine feasible combinations of A and L is presented in Table V-2. The table shows, for example, that if A = \$4 billion and L=\$1 billion, a Federal project grant rate of 63 percent would allow the same number of annual construction grant projects to be funded as the present subsidy program.

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Table V-2

Project Grant Rates $(1-\phi)$ Required to Maintain the Existing Number of Annual Construction Projects Funded

Grant-Eligible O&M Costs (L)	Authorizations (A)		
	$2	$4	$6
$1	0.55	0.63	0.67
$2	0.43	0.55	0.60
$4	0.30	0.43	0.50

Dollar amounts are in billions per year.

As indicated previously, project grants encourage the selection of the least costly abatement projects. However, unless the grant rates are allowed to vary at least among categories of projects, the cost-sharing program will fail to make the most effective use of Federal grant funds.

In order to account for this, broad categories of projects could be established, such as those defined in the Needs Survey. Within each category, the same grant rate would apply. However, the grant rate would differ across categories.

A second approach stipulates a uniform grant rate, but categories are funded separately with authorizations differing by category. A third approach could be developed in which the grant rate as well as the size of funding authorizations differed across project categories. Whichever alternative is chosen, the cost-sharing program can be designed to provide Federal funds to supplement rather than to substitute for local funding.

Modified Construction Grants: Political, administrative, and implementation constraints may substantially limit the options available to reduce the over-capitalization bias inherent in the existing Construction Grant Program. In this subsection we consider four alternatives within the constraint of funding capital costs only. 3/

3/ Two additional options are discussed in detail in subsequent chapters. They are a reduction in grant-eligible reserve capacity design sizes (Chapter VII) and elimination of industrial cost recoveries collected against the Federal grant and retained by municipalities (Chapter VIII).

The first option is simply to reduce the size of the present construction grant percentage. Note that reduction of the effective Federal cost-sharing proportion can be achieved by reducing eligible project costs as well as by reducing the Federal construction grant percentage. In either case, the distortion between the relative prices of capital and operating resources is diminished and the potential bias for communities to choose more costly abatement techniques is decreased. At the same time, the reduced size of the Federal grant per project allows a greater number of projects to receive Federal aid in any one year. Finally, the burden of abatement costs would be shifted somewhat from the Federal government to municipalities.

The second option is a subsidy to be used for construction costs, with the size of the subsidy funds provided being independent of the magnitude of construction costs. Grant rates might depend, for example, upon the population served by the project as well as upon the type of project being constructed. As long as the size of grant funds provided is less than actual construction costs, communities would not be encouraged to overcapitalize waste treatment facilities within the designated types of grant-eligible projects.

A third option has been suggested by the National Bureau of Standards [4] in their report for EPA. Several construction grant rates could be specified, depending upon the project size and type. Further, the grant rates could be set such that the effective Federal cost-sharing proportion is equalized among alternative abatement projects.

Unfortunately, unless an acceptable limited set of grant rates can be designed, a case-by-case project evaluation may be necessary, along with completely variable grant rates by individual projects. To avoid this problem, the size of the grant rate (or the set of grant rates) could be defined as the minimum of a given percentage of capital costs, or a given (lower) percentage of total project costs. This fourth option, referred to as a project grant-rate limitation, and also suggested in [4], limits the potential overcapitalization bias, and avoids the administrative problem of determining the appropriate grant rate on a project-by-project basis.

A first approximation for an acceptable wastewater treatment plant grant-rate limitation is now described. Previous research [3, 5, 6] has indicated that annual operating costs represent 7 to 12 percent of treatment plant replacement values. Suppose that the plant life is 20 to 50 years, and the discount rate is 7 percent.

Using these figures, it can be demonstrated that, in terms of present values, a 75 percent construction grant is equivalent to a project grant rate ranging from 25 to 50 percent.

By stipulating a construction grant rate equal to 75 percent, but limited to no more than 25 percent of total project costs, the bias for local communities to choose more costly projects is mitigated. The bias among those projects which receive a project grant in excess of a 25 percent rate under the existing grant program is in fact eliminated. However, the community may still prefer those treatment projects which receive a project grant equal to 25 percent of total costs to projects which receive grants of less than 25 percent of total costs, even though the former projects may be more costly to society than the latter.

Obviously, imposition of the project grant-rate limitation increases the average local burden of treatment costs, and more so as this rate is reduced in size. To minimize the effect on the local burden, while reducing the tendency for communities to prefer highly capital intensive wastewater treatment projects, the project grant-rate constraint could be set at the upper bound for the expected range of values presently observed for existing treatment plants. In this program, the amount of grant funds provided would be given by the minimum amount of funds associated with a 75 percent construction grant rate or a 50 percent project grant rate.

O&M Performance Incentives: The existing construction grant bias to undermaintain and overcapitalize wastewater projects could be mitigated by introducing O&M performance incentives as a complement to a construction grant program. New York State has a program which provides a one-third O&M subsidy to those plants satisfying criteria related to cost-effective operations [7]. The 10-year old program presently has the participation of 400 of the 500 State municipalities. Unfortunately, quantitative evidence of the program's cost-effectiveness is not presently available.

One factor affecting the desirability and acceptability of any Federal cost-sharing performance subsidy program is the cost required to fund the program. In the following discussion the potential Federal cost of a performance subsidy program is calculated.

The Federal program cost depends to a large extent on the total amount of grant-eligible O&M costs incurred each year. We avoid specifying grant-eligible O&M cost categories and performance requirements at this point, and concentrate first on estimating total annual O&M costs.

Cost and BOD removal data for 106 secondary (or higher level) treatment plants in New York State were evaluated for the year 1972. A summary of the data is presented in Table V-3. Note that the table indicates that the annual per capita waste load generated is approximately 100 pounds of BOD influent.

Next, records for all secondary (or higher level) treatment plants in the United States were scrutinized, from EPA's Storet File, to determine the total population served by each of the three plant categories listed in Table V-3. It was estimated from these records that 125 million people are presently receiving secondary or higher level wastewater treatment. Approximately 20 percent of these people are being served by small (0.1 - 0.99 m.g.d.) facilities; 30 percent by medium size facilities (1.0 - 10.0 m.g.d.); and 50 percent by large facilities (greater than 10.0 m.g.d.).

The sample results from New York State were then applied to all secondary treatment plants in the United States. The findings are presented in Table V-4. Current (1975) annual O&M costs throughout the United States for secondary treatment plants are estimated in Table V-4 to be one billion dollars.

Suppose that a Federal subsidy program is specified in which a 25 percent O&M grant would be provided for plants utilizing approved secondary or higher level treatment technology. Based on the 80 percent rate of participation in the New York State subsidy program, grant-eligible O&M costs are presently estimated to be $800 million annually. If Federal grant funds merely substituted for local funding, a 25 percent Federal subsidy would require $200 million annually in grant funds. Alternatively, if the subsidy program induced additional local spending, the Federal subsidy cost could be as high as $267 million annually. 4/

4/ In the presence of the subsidy, the maximum amount which could be spent on grant-eligible costs and still be less expensive locally than the current level of spending without the subsidy is $\$800\ (10^6)/0.75 = \$1067\ (10^6)$. The Federal cost share is then $\$1067\ (10^6)(0.25) = \$267\ (10^6)$.

Table V-3
Sample Secondary Treatment Plant Operating Data: New York State, 1972

	Plant Category		
Design Flow (m.g.d.)/ Plant Type*	0.1-0.99/T.F.	1.0-10.0/T.F.	10.0+/A.S.
Sample Size	48	49	9
Population Served per Facility	2,400	16,000	502,000
Annual lbs. of BOD Inflow per Facility (Millions)	0.263	1.584	40.843
BOD Removal Rate per Plant Category	81.0%	76.5%	76.7%
O&M Cost per lb. of BOD Removed per Plant Category (1975 Dollars)	16.8¢	11.8¢	6.8¢

*T.F. = Trickling Filter
A.S. = Activated Sludge

Table V-4

Estimated Secondary Treatment Plant Operating Results: United States, 1975

	Plant Category			
Design Flow/Plant Type	0.1-0.99/T.F.	1.0-10/T.F.	10+/A.S.	Total
Annual BOD Influent (Billions of Pounds)	2.50	3.75	6.25	12.50
BOD Influent Removal Efficiencies	81.0%	76.5%	76.7%	77.5%
Annual BOD Influent Removed (Billions of Pounds)	2.03	2.87	4.79	9.69
Average O&M Cost Per Pound of BOD Influent Removed	16.8¢	11.8¢	6.8¢	10.4¢
Annual O&M Cost ($ Billions)	0.341	0.339	0.326	1.006

A more selective subsidy program could focus upon designated O&M inputs. If these inputs are currently underutilized by treatment facilities, the selective subsidy would not necessarily induce excessive employment of the subsidized resource inputs. At the same time, the selective subsidy is capable of inducing a given level of abatement for less Federal funds compared to a program which covers total O&M costs.

For example, discussions with engineers and municipal treatment plant personnel have indicated that an important shortcoming in many treatment plant operations is the absence of a properly trained and highly qualified chief plant manager. A selective subsidy for this category of O&M costs would substantially reduce the size of needed Federal funding compared to the amount required for the broader O&M subsidy program.

In either case, previous findings have indicated that it appears desirable to reallocate some resources from construction to operating activities. Accordingly, Federal funding of an O&M subsidy program could be usefully provided from authorizations originally earmarked for Federal construction grants.

In this instance, if the Federal construction grant rate is held constant, it follows that fewer capital projects could be funded in any one year. However, by rearranging equation (3), it can be shown that reducing the capital grant rate in proportion to the reduction in available construction grant funds, the number of fundable construction projects could be held constant.

To demonstrate, suppose that authorized annual construction grant funds during the next few years are equal to $4 billion. Previous calculations have indicated that a 25 percent O&M performance subsidy program could require as much as $267 million in Federal funds. Taking these funds from construction grant funds is equivalent to a 7 percent reduction in annual authorizations for funding the construction of wastewater treatment plants. In order to subsidize the same number of annual construction projects as was originally possible, the construction grant rate would have to be reduced by 7 percent (equivalent to 5 percentage points), from a 75 to a 70 percent rate.

An alternative to Federal funding of an O&M performance subsidy program is to have the States undertake such a program. State funding could conceivably come from funds presently used to supplement Federal construction grants. The inducement for States to adopt a performance subsidy program could be achieved in one of the following ways:

1. Require that States provide funds for O&M performance subsidies in a matching ratio to Federal construction grant allotments.
2. Provide matching Federal funds for O&M costs to States adopting their own O&M performance subsidy program.
3. Provide higher construction grant allotments, or higher Federal construction grant rates, to those States which adopt an acceptable O&M performance subsidy program.
4. Subsidize capital costs with periodic Federal grants, rather than lump-sum payments to the municipalities. Amortization of capital costs by the Federal government would be subject to satisfaction of acceptable treatment plant operating performance. 5/

Output Subsidies: Up to this point, subsidy programs for improving the allocation of abatement resources have been considered only in terms of cost sharing. A somewhat different approach consists of an output subsidy as a complement to a construction grant program, in which the size of the Federal output subsidy is related to the level of abatement achieved, rather than to the amount of abatement costs incurred. In the discussion to follow, we estimate the cost-effectiveness of two alternative output subsidy programs.

Three parameters define an output subsidy program. They are the unit of measure for abatement; and the starting point at which to measure grant-eligible abatement; and the size of the per unit subsidy.

Ideally, "output" should be measured in terms of the variable which the subsidy is ultimately attempting to influence. Thus, for our purposes, the appropriate measure would be an index of improvement in water quality. However, owing to measurement problems and the interdependent relationship of different water pollution sources on water quality, it is neither practical nor possible to use a water quality index as the unit of measure for abatement. Accordingly, a proxy is needed.

5/ This option may be unacceptable to municipalities, owing to the uncertainty associated with periodic Federal funding.

The proxy chosen for improvement in water quality is pounds of BOD removed from the wastewater influent. It may also be desirable, in practice, to include a measure of the pounds of suspended solids removed from the influent as well. However, removal of suspended solids ordinarily occurs as a joint product in the removal of BOD. Also, for a given treatment plant, the distribution of the influent (in terms of pounds) between BOD and suspended solids, as well as the treatment removal efficiencies for these two pollutants (in percentage terms), are approximately equivalent. Thus, it would be an easy matter to modify the output subsidy programs generated herein to include the removal of suspended solids as an additional measure of output.

For a given per unit subsidy rate, the starting point for measuring grant-eligible abatement is an important determinant of the size of the Federal subsidy program, as well as the number of municipalities and hence the waste load affected by the subsidy. Obviously, as the abatement starting point is lowered, the Federal program cost is raised, while the waste load affected is increased.

Based on the results indicated in Table V-3, it can be expected that the removal level of BOD in the absence of an output subsidy program is between 75 to 80 percent. The most effective use of Federal funding occurs when the subsidy is paid only for incremental abatement. Accordingly, two alternative starting points are considered: the first at a 75 percent BOD removal level, and the second at an 80 percent removal level.

The size of the per unit subsidy depends upon the level of abatement which is desired. To induce a given level of abatement, it is necessary that the output subsidy per unit of abatement be set equal to the local marginal cost of abatement. Of course, the sufficient condition is that the total subsidy payment exceeds local abatement costs induced by the subsidy, i.e., local incremental costs. 6/

6/ These conditions apply when local benefits are zero beyond the starting point for the output subsidy. Otherwise, the per unit subsidy required would be less than local marginal costs, by an amount equal to local marginal benefits. At the same time, the corresponding sufficient condition is that the total subsidy exceeds the difference between local incremental costs and local incremental benefits.

Analysis of treatment plant cost data taken from [8] indicates that marginal costs increase rapidly beyond an 88 percent removal level of BOD. Consequently, the objective is to find the appropriate subsidy rates which will encourage abatement up to an 88 percent BOD removal level. To accomplish this objective, the local marginal cost of abatement at this removal level has to be found first. Subsequently, the subsidy rates are then set equal to the marginal cost of abatement.

The local marginal cost of abatement is composed of incremental construction and operating costs. However, marginal construction costs can be omitted from the local marginal cost function for the following reasons:

1. Within the relevant range of abatement, incremental annualized construction costs are estimated to be less than one-third incremental annual O&M costs [8].
2. Of the incremental construction costs required, 75 percent will presumably be borne by the Federal government; 10 to 15 percent will generally be borne by the State governments; and the remainder is likely to be borne by industry as a result of retention by the municipality of one-half of industrial cost recoveries collected against the Federal construction grant (see Chapter VIII).

The relationships inferred from [8] between the percent of BOD removed, denoted by R, and annual O&M costs, denoted by L, indicate that at a given level of R, the percentage increase in O&M costs owing to a specified increase in R is equal for different treatment plant design sizes, i.e., for $\Delta R_1 = \Delta R_2$,

$$\frac{\Delta L_1/L_1}{\Delta R_1} = \frac{\Delta L_2/L_2}{\Delta R_2},$$

at $R_1 = R_2$. The subscripts denote different treatment plant design sizes. As a result, the cost functions (expressed in terms of R) generated for each of the treatment plant design size categories should differ only by a scalar. Reference [8] also indicates that as R increases, operating costs increase at an increasing rate.

The following functional form for the abatement cost expression satisfies the above criteria:

$$L_i = a_i R_i^{\ b}, \qquad i = 1, 2, 3, \qquad (4)$$

where $a_i > 0$ and $b > 1.0$ are the parameters to be solved for, and

$i = 1$ denotes small size plants (0.1-0.99 m.g.d.)

$i = 2$ denotes medium size plants (1.0-10.0 m.g.d.)

$i = 3$ denotes large size plants (10.0+ m.g.d.)

It was possible to estimate two points on the relevant cost curves, for each of the three plant categories, using the proportionality relationships inferred from [8] and the absolute values shown in Table V-4. Substituting these three sets of two points into equation (4), it was found that, for $73 \leqq R \leqq 88$, 7/

$b = 2.833$

$a_1 = 0.1409$

$a_2 = 0.6587$

$a_3 = 9.7742$

7/ Local marginal costs increase rapidly beyond R = 88, and are estimated from [8] to be approximately four times higher at R = 91 compared to R = 88.

Let M_i represent the local marginal cost per pound of BOD removed. Note that

$$R_i = \frac{100Q_i}{X_i}, \tag{5}$$

where Q_i is the annual pounds of BOD removed, and X_i is the annual pounds of BOD influent. From Table V-4, X_i can be found. Differentiating equation (4) with respect to Q_i, the following local marginal cost functions (per pound of BOD removed) are obtained (for $73 \leqq R \leqq 88$):

$$M_1 = .0001516(R_1)^{1.833} \tag{6}$$

$$M_2 = .0001178(R_2)^{1.833} \tag{7}$$

$$M_3 = .0000678(R_3)^{1.833} \tag{8}$$

Substituting $R_i = 88$ into equations (6), (7), and (8) yields the following results:

$M_1 = 56¢$

$M_2 = 43¢$

$M_3 = 25¢$

Thus, in light of these local marginal costs, the output subsidy programs considered herein specify that the magnitude of the subsidy per pound of BOD removed is 56 cents for small size plants, 43 cents for medium size plants, and 25 cents for large size plants. Further, two alternative starting points are considered: first, at $R = 75$, and second at $R = 80$, that is, removal levels in excess of these R values will receive an output subsidy.

Based on the local cost of abatement functions, we can show that for a starting point of $R = 75$, treatment plants presently having $73 \leqq R \leqq 88$ will find it profitable to increase abatement up to $R = 88$. For a starting point of $R = 80$, treatment plants presently having $78 \leqq R \leqq 88$ will find it worthwhile to abate up to $R = 88$.

Analysis of (1) the New York State data discussed previously, (2) sample data taken from 97 secondary treatment plants throughout the country [3], and (3) data based on 58 plants chosen in a sample from Connecticut [3] indicate that approximately 75 percent of the total BOD influent load is presently being treated at or greater than a 73 percent removal level; approximately 65 percent of the total BOD influent load is presently being treated at or greater than a 78 percent removal level. These are the relevant influent waste loads which will be affected by the output subsidy programs under consideration.

To determine the incremental BOD treatment induced by the output subsidies, we assume that for BOD influent currently being treated at R = 73, the average removal efficiency is 80.5, i.e., (73 + 88)/2. Similarly, we assume that for BOD influent presently being treated at R = 78, the average removal efficiency is 83.0.

Given these removal efficiencies, the waste load influent distributed by plant sizes (Table V-4), and the local marginal control cost functions (equations (6)-(8)), the measures of cost-effectiveness induced by the two output subsidy programs under consideration have been calculated. The results are presented in Table V-5. Incremental capital costs (assumed not to be borne locally) are estimated from the relationships given in [8], in order to calculate the increase in the cost of Federal construction grants induced by the output subsidy programs.

Table V-5 shows that a Federal output subsidy program having a starting point at R = 75 is expected to reduce the existing secondary treatment plant BOD effluent by over 22 percent. The average (local) O&M cost per incremental pound of BOD removed is 36 cents, while the average social cost (including annualized construction costs) per incremental pound of BOD removed is approximately 47 cents. The current Federal cost of funding this first output subsidy program, for secondary treatment plants, is estimated to be less than one-half billion dollars annually.

Table V-5

Results of Output Subsidy Programs
(1975 Prices)

Cost-Effectiveness Measures	Option 1: R = 75	Option 2: R = 80
Incremental BOD Removed (Millions of Pounds Per Year)	700	410
Change in BOD Effluent	- 22.4%	- 12.8%
Incremental Municipal O&M Cost ($ Millions Per Year)	254	153
Average Municipal O&M Cost Per Incremental Pound of BOD Removed	36	37
Federal Output Subsidy Cost ($ Million Per Year)	459	246
Incremental Federal Construction Grant Cost ($ Millions)	629	415

An output subsidy program having a starting point of R = 80 is expected to reduce the existing secondary treatment plant BOD effluent by almost 13 percent, and incur average O&M costs of 37 cents per incremental pound of BOD removed. The average social cost per incremental pound of BOD removed is 48 cents, while the current Federal cost of funding this second output subsidy program is estimated to be one-quarter of a billion dollars annually.

Conclusions

The present Construction Grant Program encourages substantial inefficiencies in the allocation of abatement resources. Four alternative categories of Federal subsidy programs tend to increase the incentive for local communities to choose more socially cost-effective abatement projects: project grants, modified construction grants, O&M performance subsidies, and output subsidies.

Project grants provide a uniform cost-sharing proportion for both capital and operating expenses within designated categories of pollution control projects. One measure of comparison between a project grant program and the Construction Grant Program is the project grant rate which allows the same number of construction projects to be funded annually as is possible under the existing grant program, for a given level of available Federal grant funds. The project grant rates associated with annual authorizations of $2, $4, and $6 billions are estimated to be 55%, 63%, and 67%, respectively.

Several modified construction grant programs were discussed which essentially reduce the grant rate compared to the present program. They included programs in which (1) the nominal construction grant rate is reduced below 75 percent; (2) the number of grant-eligible items is reduced; and (3) construction grant funds are limited to a specified percentage of total project costs.

Performance subsidies provide an O&M cost-sharing subsidy for the adoption of designated treatment activities. A 25 percent O&M performance subsidy for grant-eligible secondary treatment plants is estimated to currently cost less than $300 million annually.

Output subsidies, where Federal payments would be made to municipalities only if demonstrable abatement results are achieved, provide an abatement incentive for existing plants, which are subject to less Federal control than new plants. At the same time, this category of programs encourages communities to undertake abatement beyond mandated treatment levels, if it is inexpensive to do so relative to the amount of the subsidy forthcoming. Output subsidies also tend to mitigate the overcapitalization bias inherent in the Construction Grant Program.

For a starting point of 75 percent BOD removal, the output subsidy program is projected to induce more than a 22 percent reduction in the existing BOD (and suspended solids) effluent for secondary treatment plants. The Federal cost of this output subsidy program for existing secondary treatment plants is estimated to be less than $500 million annually. An output subsidy program having a starting point of 80 percent BOD removal is estimated to be approximately 50 to 60 percent as effective and costly compared to the option which has a 75 percent starting point.

Owing to the incommensurability of the criteria (effectiveness, efficiency, equity, Federal funding requirements, local funding constraints, political considerations, etc.) for evaluating each of the four categories of grant programs, and the absence of important data elements (measures of benefits, community abatement response to each grant program, etc.), it is not possible to choose objectively among the grant programs analyzed. However, project grants or the modified construction grant programs appear worthwhile as substitutes for the existing grant program, while performance or output subsidies could complement a construction grant program in a cost-effective manner. Any of these options can be designed to improve upon the existing allocation of abatement resources without affecting (1) the size of the Federal commitment, (2) the annual number of construction projects funded, and (3) the distribution of the existing pollution control cost burden between Federal and local interests.

References: Chapter V

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CHAPTER VI

EVALUATION OF ALTERNATIVE ALLOTMENT PROGRAMS

The preceding two chapters were concerned with the distribution of grant funds from the Federal government to municipalities. In practice, there has traditionally been an intermediate step: the allotment of grant funds to the States for distribution to those projects having the highest priority within each State.

From the perspective of economic efficiency, the allotment process is undesirable, since it ensures that a global, optimal allocation of abatement resources cannot be achieved. An optimal allocation cannot be achieved, because allotments are made without reference to project benefits and without comparison of the merits of projects among States. Allotments were not included in Chapter IV, because only optimal allocations were considered therein.

The objective of the study to this point has been to develop grant programs which will encourage a more efficient allocation of abatement resources than is presently generated by the Construction Grant Program. This objective will continue to be relevant in our study of allotments. However, there are other criteria for evaluating the success of a Federal grant program besides economic efficiency. The most important of these other criteria is that of equity, or in a general sense, fairness of the program.

The analysis to follow suggests that both efficiency and equity can be served and the allotment process improved by splitting the construction grant appropriation into two parts: one part to be dispersed on the basis of an efficiency criterion and the other part according to an equity criterion. Based on the efficiency criterion, projects are funded according to their cost-effectiveness. Based on the equity criterion, a portion of the Federal appropriation is disbursed in proportion to the relative fiscal burden which States will incur in complying with the law.

The Current Allotment Formula and Funding Process

Historical Bases for Allotments: Throughout the history of Federal cost sharing of wastewater treatment facilities, determining a satisfactory approach for allocating appropriated funds to the States has proven a continuing dilemma. The basis for distributing the funds has changed frequently and radically over the years.

As described in Chapter II, between 1956 and 1966 allotments were based half on relative State population and half on relative State per capita income. The 1966 Amendments provided that the first $100 million of appropriated funds be allocated according to the rule that was in effect during the previous ten years, but any appropriations beyond that were to be determined entirely on the basis of population. Appropriations in fiscal year 1967 were only $150 million, so State per capita income continued to play an important role in determining allotments. By 1971, however, appropriations had grown to $1 billion, and hence per capita income of the States was no longer a significant factor in determining the distribution of the funds.

In 1972 the allotment formula was altered significantly. Dropping all consideration of population and income, P.L. 92-500 called for funds to be distributed "in the ratio that the estimated cost of constructing all needed publicly owned treatment works in each State bears to the estimated cost of construction of all needed publicly owned treatment works in all of the States." 1/ The cost estimates were to be based on a survey taken in 1971, with the results appearing in Table III of House Public Works Committee Print Number 92-50.

Subsequently, P.L. 93-243 directed that half of the money appropriated for fiscal year 1975 be distributed on the basis of all the needs and half on the basis of needs reported in Categories I, II, and IVA (treatment plants, interceptors, forced mains, and pumping stations). Cost estimates are to be taken from the 1973 Needs Survey. Also, no State is to receive less allotments than it received in fiscal year 1972.

1/ P.L. 92-500, section 205(a).

Despite all these changes, disenchantment with the allotment procedure remains.

Program Objectives: A reading of the legislative history suggests that although the relative emphasis on efficiency or equity may have changed over the years, the primary objective of the cost-sharing program, the allotment formula, and the State priority systems has been to improve water quality in an efficient and equitable manner. In the ten-year period 1956-66 when State allotments were a function of relative State per capita income and relative State population, equity and efficiency seem to have been equally important. That is, per capita income is a crude but conventional measure of ability to pay. Hence allotments based on per capita income can be considered to focus upon the objective of achieving an equitable distribution of grant funds. Population is often used to reflect the relative extent of the problem, in this case, the amount of resources needed to control pollution and the amount of benefits that will result from such an undertaking. Accordingly, allotments based on population can be considered to focus upon the objective of inducing an efficient allocation of abatement resources.

The desire to achieve a more equitable distribution of pollution control costs appears to have been an important factor influencing the revision of the allotment formula in 1972. Since the 1972 Act made secondary treatment mandatory and imposed a considerable financial burden on municipalities, Congress apparently felt obliged to make the costs (i.e., "needs") that would be incurred in meeting the provisions of the Act the basis for allotments.

On the other hand, the introduction of categorical needs as a variable in the allotment formula in 1974 may have been prompted, in part, by a desire to improve the allocation of abatement resources. Concern over efficiency considerations is also implied in the Federal guidelines to the States relating to the establishment of priorities. In formulating their priority lists the States are directed to take account of the severity of pollution, the size of the population affected, and the cost-effectiveness of the project.

Achieving effluent and water quality standards in an efficient and equitable manner is an eminently sensible objective. The justification for efficiency is self-evident: with a limited amount of Federal grant funds, it is economically desirable to induce as many net social benefits as possible.

The supporting arguments for equity are twofold: First, the 1972 Amendments were an abrupt change in legal requirements, and imposed a marked increase in financial burden on many municipalities. Although almost all emissions into navigable waters were prohibited in 1899, the law was never enforced, and de facto pollution rights evolved. It seems reasonable to provide differential assistance during the period of adjustment to the new statute. Second, the distribution of benefits from wastewater treatment and water quality improvement between communities is highly uneven. In some communities the benefits are captured locally; in others they accrue to down-stream communities. Hence, in many cases benefits are not closely related to the taxes paid and the costs borne. In these situations, equity considerations acquire additional significance.

It is desirable that the Construction Grant Program generate an efficient and equitable allocation of abatement reasources. However, the present allotment formula, in conjunction with the State priority systems, is a seriously deficient mechanism for achieving these objectives. The next two sections examine the inadequacies of the current Federal allotment formula and the State priority systems.

The Current Allotment Formula: Currently, allotments are based solely on the concept of need, i.e., the capital costs required to comply with the law. Need is conceptually inappropriate for achieving either efficiency or equity.

Need is an input into the abatement process, not a measure of the output. There is no reason why needs should be correlated with the benefits of wastewater treatment. Since need is undependable as a proxy for benefits, its use for allocating grant funds is not necessarily consistent with efficiency.

State priority lists rank projects according to their importance within each State, and presumably reflect abatement benefits. However, Federal allotments occur without any consideration of these lists, and hence without any consideration of benefits. No project-by-project comparison occurs on a nation-wide basis. In the absence of comparisons across State borders, investment errors are inevitable. In some places relatively inefficient projects will be undertaken at the expense of socially preferable projects elsewhere.

The cost of wastewater treatment reflects the absolute burden on a community, but not the burden relative to fiscal capacity. Consequently, needs alone are a very crude measure of equity. A wealthy State with extensive needs may be under no greater fiscal burden than a poor State with limited needs.

A simple allotment formula based on only one variable is attractive from an administrative point of view, but simplicity should not take precedence over the primary program objectives. There is unlikely to be one variable which can simultaneously promote two such different objectives as equity and efficiency.

Later in this chapter a procedure is considered for improving the allotment formula as well as the entire decision-making process for determining investments in wastewater treatment facilities (referred to hereafter as the "funding process").

In this procedure, appropriated funds are divided into two parts: a portion to be distributed on efficiency grounds and a portion on grounds of equity. A variety of variables are considered for inclusion in the allotment formula, with different variables being used to promote the two different objectives.

Implementing Allotments Through the Needs Survey: In its present form the allotment formula is deceptively simple. It is based on the single and seemingly easily understandable concept of the cost of complying with the law. In practice there have been numerous misunderstandings of what constitutes eligible needs, and the estimates of these needs have proven unreliable. Although the problems with the Needs Survey have been well publicized, a brief discussion of the most salient difficulties is useful here.

The allotment formula allocates the largest share of appropriations to those States with the largest estimates of costs which will be incurred in meeting the standards. The States are aware of this, and there is some evidence that they protect their share of budgeted funds by biasing the cost estimates upwards wherever possible. 2/ Although cost curves

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2/ The National Commission on Water Quality conducted a survey of States to determine (in part) the accuracy of the estimating procedures for the Needs Survey. One State wrote an unsolicited letter indicating that the costs were largely concocted to comply with the legislative requirement, but more especially to protect the State's share of Federal funds.

were provided as guidance for estimating some categories on the survey, only limited direction was given for the others, and the survey was too massive to permit EPA to thoroughly review the statistical techniques employed throughout.

States were directed to report treatment needs up through 1990 based on projected residential population, 3/ non-residential population, and industrial flows. Needs were not reported by year; only the total needs up through 1990 were provided. Even if one were committed to a program of allotments proportional to costs, total needs up through 1990 does not seem to be the relevant statistic. These needs are not an estimate of current capital requirements, and it is difficult to understand how they are germane to the problem of distributing current appropriations.

An example may help to illustrate this point. Consider two States with identical total needs and identical distributions of needs among categories. The existing treatment facilities in State A are old and require replacement now, while the bulk of State B's investments won't be needed until 1985. Despite this important difference between the two States the present allotment formula would result in each State receiving the same share of current appropriations. This is clearly not a cost-effective method for allocating wastewater treatment capital. The same anomalous result can occur due to differences in any of the variables affecting the waste stream, e.g., population growth or expected industrial concentration. It occurs because all future needs (up to 1990) are weighted equally and counted as current needs no matter when the waste stream problem is expected to arise.

In spite of these observations, the vast majority of actual needs occur during the next few years. Thus, in practice, the inclusion of future capital requirements in the allotment formula has only a minor impact on the current allotment of funds. However, retension of the existing formule may adversely affect the allotment of funds after the existing backlog is satisfied.

3/ This was not to exceed the Department of Commerce Series E projection.

The Priority Systems: Thus far we have examined the difficulties with the first stage of the funding process: the inappropriate design of the allotment formula and the practical problems associated with using the Needs Survey data to apportion Federal grant funds. The second stage of the funding process, namely the formulation, review, and approval of State priority lists, has equally disturbing features.

The priority lists are of critical importance. They are supposed to rank individual projects according to their merits, taking into account such things as the severity of pollution, the cost of the required facilities, and the number of people who will benefit. Although not formally designated as such, the priority lists are supposed to serve the function of a benefit-cost algorithm. However, there is little confidence in their validity.

A State's priority list is formed by evaluating each prospective project within the State according to a set of criteria. Some of the criteria are required by Federal Rules and Regulations, but some are established by the State. The State assigns a maximum value or weight to each criterion. A project is awarded points for each criterion, and the total points determine its ranking on the priority list.

In order to illustrate the arbitrary nature of the priority systems, the approach taken by Connecticut for ranking projects is indicated below.

Priority System Criteria

Maximum Points		
20		1. Severity of pollution problem
15		2. Population affected by the project
10		3. Need for preservation of high quality waters
5		4. National priorities (priority basins)
	15	5. Projects needed to meet enforceable provisions. 4/
	10	6. Projects desirable in terms of water quality improvement. 4/

4/ Mutually exclusive criteria.

Priority System Criteria (continued)

	5	7. Projects which are not discharges. 5/
10		8. Benefits to downstream users of receiving streams: public health and health of aquatic ecosystems, recreation, industry, agriculture.
10		9. General water quality improvement expected due to project.
85		Possible Points

Although the first four items are mandated by the Federal government, no weights are specified. The States choose the weights, and there seems to be no objective justification for the relative values assigned to each criterion. Futhermore, the method of scoring individual wastewater treatment projects within a State is likely to lack uniformity.

Because of these problems the project lists can be structured in almost any desired way. In addition to having complete freedom in assigning weights for each criterion, the States have considerable discretion in defining those which are Federally imposed and in choosing additional criteria.

Flexibility of this kind provides the States and localities with an opportunity to express their individual preferences, but it also makes it very difficult for the EPA regional offices to evaluate the priority systems and resulting project lists. In point of fact, the systems are so fraught with subjectivity that there is no objective way to evaluate them, and the regional offices have virtually no option except to approve them.

Summary of Problems with the Current Funding Process: We have identified three principal features of the present funding process which conflict with objectives of the Construction Grant Program:

1. The two stage design results in allotments being made without explicit reference to project benefits.

2. Needs, the basis for allotments, reflect neither benefits nor the burden of the program relative to fiscal capacity.

5/ Mutually exclusive criteria.

3. The priority systems, which are responsible for ranking individual projects according to their merits, are so unstructured that even within the States there is little assurance that appropriate investments are being undertaken.

It is apparent from these observations that the objectives of equity and efficiency cannot be served simultaneously through the existing allotment formula.

Alternative Formulas

The Inappropriateness of Conventional Allotment Formulas: Although allotment formulas based on relative per capita income and relative population have been used in this and other programs, 6/ reverting to a formula based solely on these variables would not serve the objectives of the program, and would perpetuate the problems inherent in the current formula and funding process. Per capita income and population are variables which provide useful information which can be utilized to promote policy objectives. However, they have to be used with care, and the objectives which they are supposed to promote have to be precisely defined.

Simply because population is likely to bear some correlation to the extent of pollution, the cost of abatement, and the demand for and potential benefits from improved water quality does not guarantee that its casual inclusion in an elementary algebraic function will promote efficient resource allocation. It is unrealistic to expect this one variable to reflect both costs and benefits and to account for the proper relationship between them.

Population is not the sole determinant of costs and benefits. Although the load on a treatment plant is highly correlated with population, the amount of treatment necessary, and hence the cost of

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6/ Allotment formulas based on these two variables are quite popular. They are currently used to determine allotments for Adult Basic Education, The National Teachers Corps, Vocational Rehabilitation, construction of hospital facilities under the Hill-Burton Act, and services and construction under the Library Services and Construction Act.

abatement, is also related to the environmental characteristics of the region. The value of benefits derived from an improved water segment are related to the type of use that is to be sustained and the availability of substitutes. If a serious attempt is to be made to achieve efficiency, these additional relationships have to be taken into account.

Furthermore, the mere addition of variables to the allotment formula will not transform the two-stage funding process into a decision-making procedure which allocates resources efficiently. A project-by-project comparison across State lines is necessary if efficiency is to be improved.

There are a number of reasons why relative per capita income is a poor variable to use to achieve equity. These are discussed in detail later. (See the section entitled "Equity Considerations.") Principal among these are:

(1) For our purpose relative per capita income is not the best variable to use to reflect fiscal capacity, and

(2) Fiscal capacity alone is not the relevant variable to use to promote equity.

The appropriate concept is the cost of abatement relative to fiscal capacity.

In the next section an alternative allotment formula and funding process is discussed which mitigates the above problems inherent in the current system. In this approach the two-stage funding process is eliminated; a uniform system for evaluating individual projects and ranking them nationally on their merits is developed; and because the approach is based on variables which reflect benefits, costs, and fiscal capacity, it improves the tendency of the funding process to promote efficiency and equity compared to the present program.

A Two-Part Allotment Formula: The dual objective of efficiency and equity can be served by splitting the wastewater treatment appropriation into two parts: one part to be disbursed on the basis of an efficiency criterion and the other part distributed according to an equity criterion. There is ample precedent for such a dichotomous structure; allotments were made in an analogous manner from 1956 to 1971.

There is no logical procedure for determining the relative proportions between equity and efficiency. Congress will have to make this decision according to its preferences. The only assistance which can be provided on this issue is that there is no reason to retain the same proportions year after year. Because the 1972 Amendments imposed large burdens on many municipalities, one might want to give greater consideration to equity during the years when communities are adjusting to this abrupt change in requirements. Once the adjustment process is complete and secondary treatment has been universally achieved, less emphasis might be placed on equity.

The remainder of this paper is devoted to developing an approach for alloting grant funds on the basis of an efficiency criterion and an equity criterion, and to discussing the feasibility and problems encountered in implementing and refining this approach. The efficiency criterion is treated first.

Efficiency Considerations

A National Benefit-Cost Ranking: This section presents an economically optimal criterion for allocating the efficiency portion of allotments, assuming that the basic form of the wastewater treatment program is retained, i.e., that the program continues to be one in which only capital is subsidized and the legislated cost-sharing proportions are uniform. The criterion is optimal in the sense that net social benefits will be maximized subject to a Federal grant (a fixed appropriation). 7/ If the subsidy program takes a different form and any of the options discussed in Chapter V are adopted, then an alternate allotment formula may have to be developed.

7/ Chapter IV also presented an economically optimal criterion for determining which projects to fund. That criterion was based on the assumptions that all treatment costs (not just capital costs) were subsidized, and that cost sharing proportions could be variable. We assume here that the grant program will not meet either of these conditions, and hence the appropriate criterion in this case not only differs from that found in Chapter IV, but in addition, is much simpler to generate.

For the specified program design, net social benefits will be maximized subject to the Federal funding constraint by ranking all proposed projects according to their benefit-cost ratios, and funding them sequentially until the efficiency portion of appropriations is exhausted. [8] The relevant benefit-cost ratio is given by the expression

$$\frac{B - C}{K} \tag{1}$$

where B = the discounted value of total abatement benefits,

C = the discounted value of total abatement costs, and

K = the discounted value of grant-eligible capital costs. [9]

The problem with implementing this ranking scheme is that it requires the estimation of benefits from water quality improvement. Although fairly reliable cost information can be obtained, benefit estimation is still in a primitive stage of development.

Estimating Benefits: A project generally results in a water segment being improved, and this improvement in the water segment will in turn generate and encourage new activities (recreational, aesthetic, life support, etc.). In order to estimate benefits the type of activities generated as a result of the improvement have to be identified, the annual amount of each activity estimated, and a value estimated for a unit of each activity.

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[8] Implicit here is the assumption that municipalities will not undertake projects without Federal funding. If there were a way to predict which projects would be undertaken in the absence of Federal subsidies, then net social benefits could be increased by devoting the Federal budget to projects other than these.

[9] For a discussion of criteria in the selection of water-resource projects see McKean [1].

Intially, this involves determining the post-installation quality of the water, the types of use that the improved water segment will sustain, and the size of the water segment that will be improved as a result of the project. This information can be obtained. Indeed, it is currently required as part of the grant application process.

Next, the amount and value of the activities have to be estimated. A water body normally has multiple uses: contact and non-contact recreation, aesthetic enjoyment, health benefits, drinking water supplies, life support for plants and animals, irrigation, industrial cooling, etc. Only some of these activities have market prices, and even for these an estimate would have to be made of the quantity that would be consumed at these prices. For others the usual approach is to attempt to approximate the number and value of the user days generated during the year. For some activities benefit estimation is simply not fruitful.

Even if all of this can be accomplished, only the gross value of the activities is estimated, while it is the net contribution which is important. Some of the activities generated by the improved water segment will replace activities formerly engaged in elsewhere, e.g., a day of fishing may be substituted for a day of golfing, or a day of canoeing on this segment substituted for a day of canoeing on another segment. The value of the supplanted activities has to be subtracted out in order to estimate the improvement in social welfare attributable to the project undertaken.

Finally, the benefits from improved water quality do not all accrue in one year. A stream of benefits accrues over time, and the annual amount may vary. Annual benefits have to be estimated for the effective life of the treatment project and their value discounted to the present.

Cost-Effectiveness Analysis: Clearly, the dimensions of the task preclude any attempt at precise estimation of the value of wastewater treatment benefits. An alternative approach is cost-effectiveness analysis. Cost-effectiveness analysis uses non-monetary output variables to form an index of benefit surrogates. The output variables chosen depend upon the objectives of the program. For example, we might decide to measure the effectiveness of wastewater treatment projects by the number of stream miles improved to a certain water quality.

The preceding section indicated that the improvement in net social benefits was the relevant measure for evaluating a project's desirability. Because an effectiveness index is not measured in monetary terms, it is not possible to net out costs, to account for supplanted activities, or to discount the value of future outputs to the present. It is only possible to measure project effectiveness during a particular time period per dollar of expenditure. Thus, an effectiveness index is an inherently less accurate measure of the value of a project than net benefits. However, as a surrogate for benefits it is preferable to the existing, amorphous priority systems.

Desirable Elements of an Effectiveness Index for the Wastewater Treatment Program: It is desirable to have an effectiveness index which closely reflects the value of benefits, that is, the product of the price of the output and the quantity of output. It would also be desirable to have an index that distinguishes beween types of uses, because not all uses are equally valuable. For example, the price of the output varies depending upon the type of activities generated as a result of improving a water segment. The price of the output is also sensitive to the availability of substitutes. If there is a large amount of high quality water in an area, additional improved segments would be less valuable compared to a situation in which only a few substitutes are available. Finally, the index should incorporate variables which reflect the amount of use, i.e., the quantity of output. Amount of use is a function of the size of the improved segment, the availability of substitutes, and the location of the segment relative to population centers. If an improved water segment will not receive much use, either because the area is remote, or the segment is small and won't support much use, or because there are numerous alternatives, then it is not nearly as valuable as it would be if it were used extensively.

Thus, the value of the benefits derived from water quality improvement depends largely on the type of use that the water body will receive, the amount of use (the number of user days), and the availability of substitutes. Variables that might be used to reflect these characteristics in an allotment formula are discussed below:

1. Type of Use: Although an effectiveness index which manifests all three of these characteristics would be desirable, estimating differential values for uses does not appear feasible. It is possible to identify the different uses that a water body will

support, but in the absence of market prices for all activities it is not possible with confidence to place relative values on different uses. Some simplifying assumptions regarding use are necessary.

There are five commonly accepted use categories: recreation (including aesthetic enjoyment), drinking water supplies, aquatic life support, agriculture, and industry. For several reasons it appears that we will not violate optimality seriously if the effectiveness index accounts only for recreational benefits.

Preliminary study shows that the dollar value of existing recreational damages from water pollution exceeds the aggregate amount of damages from the remaining use categories [2]. It is reasonable to suppose that within each use category, total damages are indicative of the relative amount of marginal damages. It follows that useful estimates of relative project benefits for incorporation in a grant-allotment formula can be obtained by focussing mainly upon recreational uses.

Moreover, in order to meet the 1977 water quality standards, receiving waters must be capable of supporting indigenous aquatic life and secondary recreation. For the most part grant-eligible projects will be required to take receiving waters from an industrial or agricultural quality to a quality suitable for fish and recreation other than swimming. Thus, it is likely that the majority of the actual benefits forthcoming from wastewater treatment projects will be recreational and aquatic life support.

Finally, the capacity to sustain aquatic life is highly correlated with water of recreational quality. If we assume that aquatic benefits are proportional to recreational benefits, it is not necessary to explicitly account for aquatic benefits in the effectiveness index. 10/

10/ Even with recreational quality water, the types of species and their relative abundance will differ, and so will the aquatic value of the improved water segment. Evaluating the aquatic benefits in any units, let alone in the same units of measurement as the recreational benefits, is extremely difficult. Hence, devising an additive index which accounts for recreational as well as aquatic benefits appears to be a remote possibility. As a practical matter, one is forced to adopt the assumption of proportionality.

There will undoubtedly be projects which generate drinking water, agricultural, and industrial benefits in addition to recreational and aquatic life support benefits. An index which accounts only for recreational benefits will undervalue such projects. Unfortunately, in the absence of market prices it is very difficult to devise an index which evaluates all types of benefits in common units, and allows them to be aggregated. If there is a low incidence of projects with multiple types of benefits (or if the inference that recreational benefits dominate is valid), then an index which accounts only for recreational benefits should prove acceptable.

With few exceptions, projects whose benefits are exclusively or primarily agricultural, industrial or drinking water should not be eligible for Federal funding, and should not be included in the index. These benefits are usually saleable, and their values can be captured locally through the market. If the benefits are sufficiently valuable, the municipality should be willing to pay to generate them without Federal subsidies. 11/ In contrast, the recreational and aquatic benefits from water quality improvement have public goods aspects, and it is much more difficult to market these.

Adopting an index which concentrates on recreational values solves only partially the additivity problem associated with diverse uses. There are numerous types of recreational activities, and they are unlikely to be of equal value. Despite this problem, it appears that the only practical method of dealing with these remaining uses is to assume that no matter what the specific form of activity (fishing, boating, aesthetic enjoyment), all man days of water recreation are equally valuable. Thus, none of the alternative indices developed below attempts to distinguish among uses.

2. Amount of Use: Direct estimation of the number of man days of use that each improved water segment will generate is complex, costly, and unlikely to provide satisfactorily accurate results. A practical surrogate variable for the amount of use is the population that lies within some specified radius of the water segment. Other things equal, larger populations should generate greater use, and persons living close to the improved segment should benefit more from it than those living farther away.

11/ The exceptions to this principle occur when transactions costs are so large as to prevent markets from forming or properly functioning. Under these circumstances government action which would result in welfare gains being realized is justified.

Resident population data is easily obtained, of course, but resident population may not be the best proxy for the population benefiting from the improved water segment. Preferences differ, and not all persons within a region are likely to make use of the improved segment. Similarly, the proportion of the resident population using the water is not likely to be constant throughout the country. Furthermore, some areas are predominantly tourist areas, and using only resident population in the effectiveness index creates a bias against projects in these locations.

It is possible to refine the population estimates, but the cost of doing so may be prohibitive. Refinements and their feasibility are discussed later. Initially we are concerned with developing an effectiveness index with a relatively simple structure and examining its implications for resource allocation. For purposes of convenience and exposition we assume that the population measure employed in the index is the resident population within a 100 mile radius of the improved water segment.

3. Availability of Substitutes: The stock of comparable quality water segments within a specified radius of the improved water body can be used to reflect available substitutes. Theoretically, non-water activities are substitutes for water activities, but it does not seem practical to attempt to incorporate these in the proxy for available substitues.

   Some arbitrariness is involved in specifying the geographic limits to the region of relevant substitutes. For purposes of and consistency with the measure of the preceding variable we use a 100 mile radius from the project site.

   Water bodies are not homogeneous, and have a variety of characteristics: length, depth, width, circumference, surface area, volume, etc. Which characteristic(s) is relevant depends in part upon the type of use that the water will receive. This topic is explored later and a possible resolution suggested. Assume for the moment that streams are the only water bodies improved by the program and that length (stream miles) is the accepted unit of measurement.

A Possible Form for the Index: Although an infinity of possible functional forms exist for the effectiveness index (E), there is no convenient way to determine which form will generate the best approximation of net social benefits. Initially an uncomplicated form is chosen which ranks projects in a desirable manner, and is based on variables whose values are easily estimated.

Other options which use more refined variables are discussed subsequently.

Let $E = P^a (P/W)^b (dW/W)^c$,

where P = the resident population within a 100 mile radius of the improved water segment,

W = the stock of water (measured in stream miles) within a 100 mile radius of and comparable in quality to the improved segment,

dW = the length of the improved segment. 12/

The symbols denoted by a, b, and c represent positive scalar parameters. The expression dW/W represents the percentage change in the area's stock of water which is generated by the investment in the treatment project. For a given dW, this expression will have a smaller value in relatively water-rich regions, and will produce an effectiveness index having a smaller value than it would in more arid regions.

The population per stream mile, denoted by P/W, is a density variable. It provides an indication of how crowded the area's recreational water facilities are likely to be. If the region is rich in water relative to the population, E will tend to be lower than if the region has a meager stock of water.

12/ It should be noted that this effectiveness index is not appropriate for ranking wastewater treatment projects which must be installed in order to comply with effluent standards, but which do not improve the water quality sufficiently to upgrade the use of the water segment. Such projects do not increase the stock of water available for any particular use, and hence no new activities are generated. Thus, $dW = 0$, and $E = 0$. This does not appear to be a serious problem. It is estimated that less than 5 percent of the construction funds required to comply with the law will be devoted to such projects.

Consider two areas with identical values for P/W and dW/W, but one area is more populated. More benefits are likely to be generated in the area with the larger population, because more people will be using the water. The above functional form for the effectiveness index reflects this, since E increases with increases in P.

The parameters a, b, and c are discretionary; there is no objective way to determine values for them. By altering the size of these parameters, one can alter the relative effect of the statistics P, P/W, and dW/W on E.

Of course, E is only the numerator of the cost-effectiveness index. Eligible capital cost constitutes the denominator. For a given level of effectiveness, a higher capital cost reduces a project's cost-effectivenss ratio (E/K) and the likelihood that it will receive funding. This is as it should be, because for the limited appropriation we wish to undertake those projects which will maximize $\sum E_i$, the aggregate magnitude of effectiveness, where $E_i = B_i - C_i$ in equation (1).

This option for a cost-effectiveness index has some appealing characteristics: it ranks projects in a manner consistent with improved resource allocation, and is based on variables that are easily estimated. However, a cost-effectiveness ranking scheme represents a major structural change from the existing funding process. Before discussing more complicated cost-effectiveness indices, the administrative feasibility of this option relative to the present system of allotments and priority systems is examined.

Feasibility of a Cost-Effectiveness Ranking: The initial reservations about an allotment system which requires a cost-effectiveness analysis for all proposed projects and distributes funds based on the relative ranking of projects are that it appears to be a radical, complicated departure from the present program design, and that it might increase administrative expenses markedly. Neither concern seems well founded.

The present Construction Grant Program requires analogous project evaluations. Currently, States have to make cost estimates for proposed projects when completing the Needs Survey. States and municipalities also have to engage in a form of benefit analysis during the preparation of the priority lists. Among other requirements, each State has to submit an annual assessment of water pollution problems; a ranking of State water segments, taking into account severity of pollution, population affected, need for preservation of high-quality waters, and other national priorities; and an explanation of its criteria for project selection. Thus, substituting a cost-effectiveness ranking procedure for the current program requirements would not involve a radical change in design. States have to conduct these kinds of activities now.

Since the cost-estimating procedures would be virtually unchanged, cost-estimation would not be a source of increased administrative expense. However, an increase in the accuracy of the estimates could be expected. The present incentive for States to bias their cost estimates upward in order to protect their share of allotments would be eliminated. If they continued to overestimate their costs in an effort to obtain greater funding, the States would jeopardize the ranking of their projects. If they underestimated their costs in order to improve the project rankings, they would jeopardize the size of their grant.

Thus, whether substituting a cost-effectiveness ranking scheme for the present system would add substantially to administrative costs depends entirely on the degree of refinement desired for the variables in the effectiveness index. If the effectiveness index employed the variables defined in equation (1), there would be virtually no additional administrative costs associated with determining the value of E for a project. Population data are readily available from the census, and EPA maintains an updated inventory of waterways and their quality. Administrative costs are likely to rise rapidly, however, if more precision is required. Below we discuss the problems associated with developing more precise effectiveness indices by (1) improving the estimate of the user population, (2) altering the units of measurement for the water, and (3) divising a substitute for discounted future values.

Alternative Population Measures

Three possible refinements of the user population estimate are discussed in this section: (1) including nonresident users in the estimate; (2) refining the estimate for a given municipality based on expected differential rates of participation in recreational water activities; and (3) refining the estimate for a municipality based on the distance that the municipality lies from the improved segment.

1. Nonresident Users: An effectiveness index which includes only resident population creates a bias against projects that would be heavily used by tourists. Any solution to this problem would probably require careful sampling, and the expense might make it impractical. In some areas data on motel and campground registrations are available, and could be used to approximate the population of nonresident users. It would be surprising, however, if record-keeping practices were uniform in all areas and constituted an acceptable sampling design. Reliance on available information simply because it is accessible is likely to introduce biases, and the cure may be worse than the problem.

The availability of recreational water facilities may not be the specific feature of an area responsible for attracting vistors. In such locations inclusion of the tourist population in the effectiveness index would inflate a project's rank.

One possible approach to this problem might be to develop an initial screen for distinguishing between those areas that attract tourists because of their water recreational aspects and those that do not. An appropriate procedure for sampling the nonresident population would still have to be devised for the former group, however.

2. Differential Participation Rates: Because preferences differ, not all persons (residents or nonresidents) within an area benefit equally from recreational water facilities. Activity participation rates have been estimated based on demographic characteristics (income, sex, age, race, place of residence, etc.). 13/ If the information necessary to utilize these participation factors were readily available through the census, it would not be difficult to modify the population weights in the effectiveness index. However, it is unlikely that information in sufficient detail exists for all municipalities and their environs. In that case, sampling would be necessary, and sampling of this kind is very expensive.

3. Differential Distance Weights: Persons who live closer to recreational water facilities probably use them more and benefit from them more than those who live farther away. One way to account for this in the effectiveness index is to assign differential weights to persons living within the 100 mile radius of the improved water segment. The weights would be a function of the inverse of the distance which a person lived from the segment, and persons living farther away would acquire less significance in the index.

13/ See Mueller and Gurin [3].

For example, let

x_i = the distance from municipality i to the improved water segment, where $x_i \leqq 100$ miles, and

P_i = the population of municipality i.

A possible substitute for $P = \sum_i P_i$ in the effectiveness index is $P' = \sum_i (1/x_i)^d P_i$, where $d \geqq 1$.

Although this option may sound involved, it is a simple and inexpensive task to incorporate a variable like P' in the effectiveness index. A modest amount of clerical work is required. If a procedure is adopted for including non-resident population in the effectiveness index, distance weights can be applied to it, as well.

Measuring the Amount of Water Resources: The appropriate units in which to measure the size of a water segment improved by a wastewater treatment project as well as the inventory of available substitutes depend upon the use for which the water is designed. If the relevant uses are drinking, irrigation, or industrial processing, a measure of volume per unit time is appropriate. For swimming, boating, and fishing, length or surface area and a minimum depth seems relevant. For purposes of environmental values and aesthetics, it is difficult to decide what measure to use. The fact that different uses require different units creates a potential problem, because if cost-effectiveness analysis is to be applied, projects have to be comparable, and a common unit of measure has to be stipulated.

Two considerations tend to simplify the problem. First, since recreational benefits are a primary concern, volume is not a relevant measure. Second, the receiving waters for effluent are primarily rivers, streams, and oceans. For many of the recreational activities on these water bodies, length (stream miles or shoreline) would be a relevant feature. However, use of length alone to measure the recreational resources might create some distortions. For instance, a mile of a wide river or a mile of ocean beach can certainly support a greater variety and amount of activity than a mile of a narrow creek. Thus, although length might serve as a rough approximation of the amount of resources, one might feel more comfortable if some of the other distinguishing characteristics of the water bodies could be captured, as well.

One option is to establish a classification of waterways based on depth as well as width or surface area. An arbitrary numerical weight could be assigned to each class, with larger water bodies receiving higher weights. Then, instead of W and dW in the effectiveness index being measured in length alone, they would be measured in length times the relevant weight. The weights serve to distinguish the carrying capacity of the water bodies or the number of user days that they will support. Some preliminary research on relative carrying capacity could reduce the degree of arbitrariness associated with choosing the weights.

Discounting Future Benefits: One of the problems with the current allotment formula is that it utilizes all needs up to 1990 in determining State allotments, and counts a dollar of needs in any one year as equivalent to a dollar of needs in any other year. This is an improper procedure, because the value of a dollar ten years from now is less than the value of a dollar today. Future dollars have to be discounted over time using an appropriate interest rate in order to make them comparable to current dollars.

In its present form the cost-effectiveness index suffers from a similar problem. Wastewater treatment projects generate outputs and benefits over a time span. The annual outputs and their values need not be uniform throughout the life of a project. Productive life spans differ among projects and originate in different years. For purposes of comparison we would like to be able to monetize the annual outputs, discount them, and determine the present value of each project.

However, the monetary values of the outputs are unavailable or difficult to estimate. In the absence of monetary values, discounting is impossible, and no alternative approach is suggested in the cost-effectiveness literature. Cost-effectiveness analysis normally assumes that benefit streams are of equal length and begin in the same year, and the annual outputs and benefits are uniform. When these assumptions hold, the effectiveness index has a constant, annual value. These assumptions are invalid in the case of wastewater treatment projects, and it is not apparent which year's statistics to use in evaluating two important variables in the effectiveness index: the user population and the stock of water.

Since the essence of discounting is to create comparability between benefits in different time periods so as to avoid committing too much capital to projects whose benefits are not realized for some time, a procedure which utilizes time-oriented eligibility criteria might be a suitable substitute. The criteria could be used as a screening device to reduce the number of projects eligible for inclusion in the cost-effectiveness ranking. For example, preference might be given to projects necessary to meet the 1977 water quality standards. A second criterion might be that projects that are not expected to be operating and producing benefits within, say, the next 6 years are ineligible for current funding. As a result, projects that previously could only be justified on the basis of benefits expected well in the future would no longer qualify for support.

There is no theoretically satisfying way to determine which year's statistics to use in estimating the user population and the stock of water. Since it seems inappropriate to base the investment decision on one year's data, an averaging procedure might be developed, e.g., the arithmetic average of the effectiveness index for the first five years of operation occurring within a decade of the year when funds were appropriated.

Equity Considerations

In the preceding sections we have discussed how to revise the allotment formula in order to improve the efficiency of the investment funding process. Efficiency is only one criterion of the cost-sharing program. In this section we examine alternatives for implementing the second criterion: equity. An index is developed which can be used to determine the distribution of equity funds among the States, and alternatives to this index are briefly discussed. In addition, problems associated with determining how the funds are to be spent within the States are examined.

The purpose of distributing a portion of the funds on the basis of equity is to provide some fiscal relief in those communities where the 1972 Amendments imposed a disproportionate financial burden. The data requirements for an equity index make it very difficult to develop an index at the community level. Consequently, an index to distribute funds among the States is proposed. The implications of this for achieving equity among communities is discussed later.

The Relevant Cost Concept: As previously mentioned, program cost relative to fiscal capacity is generally a better indicator of burden than either cost or fiscal capacity alone. Cost and fiscal capacity can be measured in a variety of ways, however, and the implications for equity can be quite different.

It has already been pointed out that the Needs Survey estimated costs by aggregating all (undiscounted) capital requirements up through 1990. This is not an appropriate statistic to use in determining either the current burden on a State or the distribution of the current appropriation. Current capital requirements is the relevant statistic. 14/

14/ Operation and maintenance expenses are also a burden imposed on communities by the 1972 Amendments. However, research has shown that these expenses are approximately proportional to the capital costs of a project. See [4, 5, 6]. Consequently, the equity index need not explicitly account for them, because they will not alter the relative financial burdens incurred by communities.

These capital requirements differ depending upon what assumption is made regarding compliance with the law. Assume initially that communities will comply with the law whether or not they receive Federal funding, i.e., funding from the efficiency portion of the appropriation. Define

$k_j = \sum_i K_{ij}$ = the total, current, grant-eligible capital costs of all i projects in State j necessary to comply with the 1977 water quality and effluent standards plus the capital costs of all those projects which must be undertaken now, if they are to be completed in time to comply with subsequent standards.

ψ_j = the proportion of k_j funded under the efficiency portion of the appropriation.

In this case the relevant current capital costs borne by State j is given by

$$(1 - \psi_j)\, k_j.$$

If it is assumed that communities will not have to comply with the law and that they will be required to undertake only those projects funded under the efficiency portion of the appropriation, then define

$\bar{k}_j$ = the total, grant-eligible capital costs of all i projects in State j funded under the efficiency portion of the appropriation, and

ψ_o = the legally mandated uniform cost-sharing proportion.

The relevant current capital costs borne by State j is now given by 15/

$$(1 - \psi_o)\bar{k}_j .$$

15/ Note that $\psi_j = \psi_o \bar{k}_j / k_j$, where $k_j \geqq \bar{k}_j$. In the current legislation, $\psi_o = 0.75$.

Measuring Fiscal Capacity: Having identified the appropriate cost concept, it remains to determine a measure of fiscal capacity with which to compare it. Fiscal capacity of a State does not mean the statutory tax base, but rather the potential tax base. The fact that a State has revenue sources which it chooses not to tax should be irrelevant to the Federal government's determination of how to distribute equity funds.

Neither per capita income nor total personal income are by themselves completely satisfactory measures of a State's fiscal capacity. Both are relevant in determining a State's ability to bear program costs. A State with a relatively high per capita income, but a small population could be seriously burdened by abatement costs, because it may have a small tax base. Thus, a total rather than a per capita concept is appropriate. However, in a State with a large tax base the burden on individual taxpayers could be substantial, simply because the base is comprised of a large population with a low per capita income.

A concept which avoids the disadvantages of both per capita income and total personal income, but retains the fiscal capacity information inherent in both of them is the sum of personal income in excess of some specified low income level, e.g., the poverty level. States with a large low-income population would be assigned a relatively low fiscal capacity under this definition, as would States with a high per capita income but a small population.

Income information of this kind is readily available from the census, and is updated annually by the Current Population Survey. This type of information is not easily obtained for municipalities, which is why we have chosen to develop a State equity index rather than a municipality equity index.

Of course, there are tax bases other than personal income which might be included in the fiscal capacity measure: personal wealth, personal and corporate property, and corporate income. 16/ Personal and corporate property information are available by State, but estimating personal wealth and corporate income would pose considerable statistical problems.

16/ Retail sales have not been included in this list, because the regressive nature of the sales tax together with the fact that in some States non-residents may account for a sizable portion of the revenues makes it an inappropriate revenue source for purposes of wastewater treatment.

The Equity Index: There are numerous functional forms for the equity index. One option appears below. Under the assumption that States would comply with the law whether or not they received funding, State j's percentge of appropriated equity funds is given by

$$\Omega_j = \frac{(1 - \psi_j)k_j / Y_j}{\sum_j (1 - \psi_j)\, k_j / Y_j} ,$$

where $Y_j = \sum_i (y_{ij} - y_{pj})$

= the sum of all personal income in State j in excess of poverty level,

y_{ij} = the personal income of individual i in State j,

y_{pj} = the poverty level in State j, and

$y_{ij} - y_{pj} = 0$ for $y_{ij} < y_{pj}$.

If States will only be required to undertake those projects funded under the efficiency portion of the appropriation, then

$$\Omega_j = \frac{k_j'/Y_j}{\sum_j k_j'/Y_j} .$$

In both cases Ω_j gives a measure of the fiscal burden of wastewater treatment in State j relative to the burden in all States. States with a relatively high burden will receive more equity funds than those with a low burden.

The Distribution of Equity Funds to Communities: The purpose of the equity fund is to provide some fiscal relief to those communities experiencing a disproportionate wastewater treatment burden. However, because financial data at the community level is more difficult to acquire than at the State level, the equity index was devised to determine an allocation of funds to the States. Without some additional restrictions there is no guarantee that the States will dispense their allocations to the neediest communities.

States could be required to develop a systematic procedure for distributing these funds in a manner consistent with the equity goal. Unfortunately, a system as nebulous as the current priority system is the likely result of such a requirement. Considerable Federal administrative problems could be avoided if no such requirement were imposed. Even without Federal involvement in local distribution, equity is likely to be served at least in part, because the funds are allocated to the States based on the relative burdens which they are experiencing. If State authorities choose not to dispense the funds to the neediest communities within their borders, they risk a political problem with their constituencies. As a contingency the Administrator could request authority to oversee the local distribution of the funds in the event that the equity goal is flagrantly disregarded.

Even if States were granted complete discretion in choosing the communities that would receive the equity funds, in the interests of preserving some incentive for efficiency the Federal government might want to place a limit on the amount of Federal financing that any one project could receive. For example, the maximum Federal share of eligible capital cost might be restricted to 85 percent. In this way local communities would still bear part of the burden of abatement, and would have an interest in cost minimization.

Rewarding Additional Abatement

A possible program objective not yet addressed is that of encouraging States to engage in pollution control which has not been Federally funded. One way of doing this would be to create a third part to the allotment formula: a separate appropriation could be established to reward States which had either undertaken projects not funded with equity or efficiency money or had incurred abatement expenditures in excess of those necessary to match these Federal funds. Whatever criterion were used to determine a State's eligibility for such reimbursement, it is not clear that this would be a desirable use of Federal funds.

The effect of such a fund would be to extend additional discretion to the States regarding which projects to undertake. There are only two grounds on which the granting of this discretion can be justified: first, if there are reservations about the accuracy of the cost-effectiveness index, and second, if political considerations require that States be given more control over the program. Only the first of these requires discussion.

If the index is considered reliable, then it is a waste of Federal funds to reward States for undertaking projects which are not cost-effective. There are more urgent projects which need funding. However, if there are reservations about the index, then a discretionary fund could be justified. It would allow States the opportunity to undertake projects which they deem important despite the relatively low rankings indicated by the index. The fund could serve as a substitute for an appeals mechanism, thereby reducing administrative expenses. Although it might not entirely obviate the need for an appeals process, it would defuse a number of potential disputes, and reduce the amount of administrative review.

If a discretionary fund were established, one would probably not want to permit States to have complete freedom of choice in the use of Federal equity funds. Furthermore, the Federal cost share for rewarding additional abatement would have to be less than that for cost-effective projects, or the advantages of the cost-effectiveness ranking could be vitiated. States would be able to undertake projects that were not cost-effective with the assurance that they would be reimbursed next year by the full amount of the capital subsidy, just as if the project had been cost-effective.

Summary and Conclusions

Since the annual appropriation of funds for wastewater treatment facilities is insufficient to undertake all eligible projects simultaneously, decisions have to be made regarding how best to utilize the limited budget. The appropriate decision rule for allocating the funds depends upon the objective of the program. In this chapter we examined (1) the objective of the program, (2) the existing project funding process, and (3) several alternatives for improving the process.

The legislative history together with the Federal rules and regulations suggest that the primary objective of the program is to improve water quality in an efficient and equitable manner. The present program design is ill-suited to achieving this objective.

Funding is currently a two-stage process. The initial step is the determination of allotments or the proportion of the appropriation granted to each State. The second stage consists of: the development of State priority lists; their review, revision, and approval by EPA; and the ultimate granting of project funds, generally in accordance with the approved lists.

There are three principal features of this process which conflict with the program objective:

1. The two-stage design results in allotments being made without reference to project benefits; no comparison of the merits of projects is made between States.

2. State needs, i.e., the estimated capital cost of required projects, which are the basis for allotments, reflect neither benefits nor the burden of the program relative to fiscal capacity.

3. The priority systems, which are responsible for ranking individual projects according to their merits, are so unstructured that even within the States there is little assurance that appropriate investments are being undertaken.

Allotment formulas used in other programs were examined. It was found that they had features which would perpetuate the problems inherent in the current formula and funding process.

The funding process can be improved, however, by splitting the wastewater treatment appropriation into two parts: one part to be disbursed on the basis of an equity criterion and the other part according to an efficiency criterion. Assuming that the program continues to be one in which only capital is subsidized and cost shares are uniform, the efficiency criterion which maximizes net economic benefits is: rank all proposed projects according to their benefit-cost ratios (i.e., net economic benefits relative to capital cost) and fund them sequentially until the efficiency portion of the appropriation is exhausted.

Because it is difficult to estimate and monetize the benefits from water quality improvement, it is not feasiible to implement this optimal allocation procedure. As an alternative to cost-benefit analysis, a cost-effectiveness approach was developed: variables, chosen to reflect the benefits from water quality improvement, are combined into an effectiveness index, and projects are ranked and funded according to their cost-effectiveness ratios.

The value of the benefits derived from water quality improvement depends largely on the type of use that the water body will receive, the amount of use, and the availability of substitutes. Variables which reflect amount of use and the availability of substitutes were developed, but it is not presently possible to develop variables which distinguish among types of uses. It was shown that this is probably not a serious inadequacy, and that an improvement in efficiency is likely even in the absence of variables which distinquish among uses.

It was shown that substituting a cost-effectiveness ranking procedure for the current program requirements does not involve a radical change in program design, and need not be expensive to implement. In the course of complying with current program requirements, States now conduct many of the activities necessary to implement a cost-effectiveness procedure. A specific cost-effectiveness index was presented which ranks projects in a manner consistent with improved resource allocation, and is based on variables that are easily estimated. However, administrative costs are likely to rise rapidly if more precise and sophisticated variables are introduced into the index.

An equity index was devised based on program cost relative to fiscal capacity. The proportion of the equity appropriation which a State receives depends upon the fiscal burden of wastewater treatment in that State relative to the burden in all States.

References: Chapter VI

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CHAPTER VII

OPTIMAL RESERVE CAPACITY FOR MUNICIPAL WASTEWATER CONSTRUCTION PROJECTS

A major concern in the planning of wastewater construction projects is the level of reserve capacity which should be provided. Reserve capacity is the treatment capability available in excess of that level needed to service the "existing" population.

The level of reserve capacity in conjunction with the expected growth in demand for wastewater treatment services defines a project design period, which is the expected time interval between expansions of a pollution abatement project. This chapter considers the optimal design period for a broad class of treatment plant and interceptor sewer construction projects. The findings indicate that existing wastewater project plans call for design periods which are almost twice the optimal duration.

As a result, the planned level of reserve capacity and hence the design size of wastewater construction projects will be too large. This observation suggests not only that the allocation of pollution abatement resources will be non-optimal, but also that the size of the Federal cost share, especially in terms of short-run wastewater project funding, will be unnecessarily high.

The size of the short-run Federal funding commitment is of serious import, inasmuch as present estimates of the costs needed to meet Federally mandated wastewater treatment requirements substantially exceed original estimates of these cleanup costs. Accordingly, this chapter considers several options for limiting the Federal financing role by redefining the grant-eligible project design period.

The analysis shows that as a result of using the optimal design period for defining project grant eligibilities, the required amount of Federal construction grant funds for secondary treatment plants and interceptors could be substantially reduced. Estimates made herein indicate that this reduction is in the range of 20 to 36 percent.

Capacity Expansion Cost Model

Evaluation of regional EPA policies in regard to reserve capacity has indicated general use of a 20-year design period for wastewater treatment plants, and up to a 50-year design period for interceptors [1]. Accordingly, construction costs required to provide treatment and collection services sufficient to satisfy demand over the stipulated design periods are eligible for a Federal construction grant.

As a result of the allowed design-period eligibility; uncertainties in forecasted demand and in continuation of future Federal funding programs; and economies-of-scale in abatement projects, communities have a strong incentive to adopt a design period which is at least equal to those allowed for grant funding. This section investigates the efficacy of the existing design-period eligibilities, through application of a capacity expansion cost model whose basic form was suggested by Energy Resources [2].

Suppose that within a community, existing wastewater treatment capacity is just sufficient to satisfy the existing population, plus population growth during the time interval necessary to provide expanded capacity. Treatment inefficiencies associated with not having sufficient capacity cannot be tolerated. Given the cost of expansion (expressed as a function of expansion design size), the interest rate, and the annual growth in demand for treatment services, the objective is to determine the optimal design period for treatment works expansion. Equivalently, we want to know the optimal time interval between treatment plant expansions.

The following assumptions are made:

1. Demand is a known and linear function of time.
2. The cost of capacity expansion and the time period required to construct expanded capacity are known and deterministic.
3. Existing capacity, and each subsequent expansion, remain operational forever, through maintenance and replacement.

The following symbols are defined:

T_u = design period (years) for the u th expansion, measured from the point in time at which the new, expanded capacity is available, to the point in time at which demand is expected to exhaust this expansion.

G_u = design size of the u th capacity expansion, measured in terms of millions of gallons per day (m.g.d.) of influent which can be treated.

r = annual, absolute growth in demand (m.g.d. per year).

i = social discount rate.

$C_u(G_u)$ = Present value, at the time of the u th expansion, of all capital and future operating and maintenance costs associated with the additional capacity provided at the time of the u th expansion.

$S(G)$ = present value at time $t=0$ of all $C_u(G_u)$.

Suppose that the present values of expansion costs (capital and operating) at the beginning of a new expansion stage are equal for each expansion. That is, the $C_u(G_u)$ are equal for a given G for each u. Since growth in demand is constant (equal to r per year), the optimal design periods T_u*, and the optimal expansion sizes G_u*, will also be equal for each u. As Thomas [3] and others have pointed out, this result is due to the fact that the decision problems at each decision point are identical. Thus, it is now appropriate to eliminate the subscript u from G_u, T_u, and $C_u(G_u)$.

It can be shown that the present value of an amount C(G) discounted n times per year over T years is

$$C(G)[(1+i/n)^{-nT}].$$

The limit of this expression as n approaches infinity is

$$C(G)e^{-iT},$$

where $e \cong 2.718$ is the base of a system of natural logarithms.

Thus, the expression for S(G), assuming continuous discounting, can be written as

$$S(G) = C(G) \sum_{u=0}^{\infty} \left\{e^{-iT}\right\}^u \tag{1}$$

The standard equation used to express capacity expansion costs is given by

$$C(G) = \alpha G^{\beta} , \qquad (2)$$

where α is a scalar and $0 \leqq \beta \leqq 1.0$ represents the relative degree of economies-of-scale in capacity expansion costs.

The deterministic assumptions for growth in demand, and for the time period needed to construct expanded facilities, suggest that it is not economically beneficial to provide expanded facilities as long as excess capacity exists. Further, the stipulation that capacity shortage is not allowed implies that expansion must be provided before demand exceeds treatment (or collection) capacity. Accordingly, it follows that the size of the expansion is given by

$$G = rT. \qquad (3)$$

Substituting (3) into (2), and rewriting (1) yields

$$S(G) = \frac{\alpha (rT)^{\beta}}{1-e^{-iT}}. \qquad (4)$$

The value of the design period which minimizes the present value of the costs of facility expansions is found by first differentiating (4) with respect to T, and setting the result equal to zero. After rearranging terms, the following equation obtains:

$$\frac{\beta}{i} = \frac{T}{e^{iT}-1}. \qquad (5)$$

Solving equation (5) precisely for T is tedious. To simplify matters, the approximation provided by Thomas [3] is used, where

$$T^* \cong \frac{6}{i}(1 - \beta^{1/3}), \qquad (6)$$

and hence

$$G^* \cong \frac{6r}{i}(1 - \beta^{1/3}). \qquad (7)$$

Thus, the optimal design period, T^*, is independent of the growth rate, r, and the scale parameter α.

The solution of equation (6) for values of β and i relevant to treatment plants is presented in Table VII-1. The resulting range of the optimal design period is $4 \leqq T^* \leqq 19$. Only at the extreme upper-bound solution does the theoretical findings approximate the presently used 20-year grant-eligible design period.

Accordingly, the justification for using the 20-year design period must rest upon the assumption of values for β and i which appear to be lower than is generally accepted. The most likely values are $\beta = 0.7$, $i = 0.07$, which yield $T^* = 10$. Also, if we suppose that each of the nine combinations of β and i in Table VII-1 are equally likely, the average value for T^* is also 10 years.

A similar analysis was conducted for values of β and i relevant to interceptors. The results are shown in Table VII-2. The entire range of T^* values is less than the presently allowed design period for grant eligibility. The variability in β values for interceptors is greater than that observed for treatment plants. As a consequence, it is difficult to narrow the potential range of β that is shown in Table VII-2. However, using $i = 0.07$, we find that for $0.3 \leqq \beta \leqq 0.5$, the values of T^* range

Table VII-1
Optimal Design Period (Years): Treatment Plants

i:	β: 0.6	0.7	0.8
0.05	19	13	9
0.07	13	10	6
0.10	9	7	4

Table VII-2
Optimal Design Period (Years): Interceptors

i:	β: 0.3	0.4	0.5
0.05	40	31	24
0.07	28	22	17
0.10	20	16	12

between 17 and 28 years. 1/ Also, weighting equally each of the nine combinations of β and i presented in Table VII-2, the average value for T* is found to be 23 years.

Sensitivity Analysis

This section analyzes the effect on the optimal design-period of modifications in the model assumptions and parameters.

Linear Growth: Alternative assumptions are that growth is either exponential or asymptotic in nature. In the latter case, a corresponding linear function can generally be found which represents a "good" approximation to the asymptotic curve. In the exponential case, Berthouex [4] has shown that optimal design periods are shorter than in the linear growth case. Accordingly, the arguments in the last section would therefore be strengthened by substituting exponential for linear growth.

Deterministic Growth: Berthouex [4] has also considered stochastic growth in the form of a uniform probability distribution. His results indicate that, in these cases, the optimal design period would be somewhat shorter than in cases of deterministic growth. In fact, the greater the variance of the uniform probability function, that is, the higher the level of uncertainty, the shorter is the optimal design period. Once again, relaxation of our model assumptions is seen to strengthen the previous fundings.

Interest Rates: Determination of the appropriate discount rate has traditionally proved elusive. Since the analysis assumes constant prices, it is reasonable to use a rate which is lower than the nominal rate observed in the market, inasmuch as the latter includes an expected inflation factor.

In any event, interest rates higher than 7 percent imply shorter design periods than those previously calculated, as seen in (6). On the other hand, use of a 5 percent rate increases the optimal design period by approximately one-third, which is still considerably shorter than those intervals presently being adopted in practice.

Economies-of-Scale: The β exponent in the capacity expansion cost function is inversely related to economies-of-scale. There is evidence [2] that both capital and O&M costs yield similar β exponents for a given

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1/ Note that lower values of β imply higher levels of economies-of-scale, and hence larger values for T*.

type of treatment project. However, when O&M yields less economies-of-scale than capital, the average value for the β exponent is increased, and T* is then even shorter than previously calculated, as seen in equation (6).

Growth Rate: Intuitively, it would seem reasonable to conclude that higher growth rates are related to longer optimal design periods. However, equation (6) shows that the optimal design period is, in fact, independent of the growth rate. Of course, as seen in equation (7), the size of the optimal capacity expansion is directly related to the growth rate.

Penalty Costs: One of the model requirements is that demand is not allowed to exceed design capacity. This assumption implies that the cost of not providing sufficient capacity, in terms of treatment requirements, storage costs, and legal sanctions, is prohibitive.

Thomas [3] has explicitly considered capacity shortage by incorporating a penalty price in the capacity expansion cost function. The relative penalty price is defined as the ratio of the penalty price per unit of capacity shortage, s, to the capacity cost associated with an additional unit of expansion when economies-of-scale are absent. Of course, this latter cost is given by the parameter α in equation (2). Thus, the relative penalty price is denoted by s/α. Prohibition of capacity shortage is equivalent to assuming that s/α is very high; strictly speaking, in this case, $s/\alpha = \infty$.

The sensitivity of T* to reductions in s/α increases as both i and β increase. However, as i and β increase, T* declines, which tends to offset reductions in s/α.

For example, suppose $i = 0.15$, and $\beta = 0.6$. Comparison of the optimal design period for cases in which $s/\alpha = \infty$ versus $s/\alpha = 0.1$ shows that the reduced penalty price doubles the optimal design period compared to our model findings. However, this higher T* is still only 13 years. Similarly, when $i = 0.05$ and $\beta = 0.9$, reducing s/α from ∞ to 0.1 doubles T*, but in this case the optimal design period is still only 7 years.

Capacity Expansion Cost Function: The appropriateness of the exponential function for estimating capacity expansion costs has been repeatedly validated in the literature. An extensive list of relevant references is provided in [2]. Nevertheless, the model does not explicitly consider the relationship between capacity utilization and operating costs.

Rasmussen and Pisano [5] have shown that unit operating costs decline as capacity utilization increases. Since plants having shorter design periods will operate at higher levels of capacity utilization compared to plants having longer design periods, it follows that the shorter designed plants will also incur lower operating costs. This finding strengthens our conclusions with regard to the advisability of reducing the existing grant-eligible design periods.

Fixed Costs: Some portion of planning, administrative and legal expenses are usually independent of the expansion size, G. That is, these costs are fixed per expansion.

Nevertheless, the total amount of these fixed costs incurred during a given time interval depends upon the number of expansions per unit time. Therefore, it follows that these "fixed" costs, expressed in terms of dollars per unit time, do depend upon G.

Surprisingly, the capacity expansion cost model is complicated considerably when fixed costs are taken into account. Further, in this case it is difficult to generalize the findings, because T* is then dependent upon β and i, as well as upon α, r, and the size of the fixed costs.

In order to test the sensitivity of our findings to the magnitude of fixed costs, a break-even analysis was conducted. The objective was to determine the size of fixed costs per expansion, relative to variable capacity expansion costs, C(G), needed to equalize the sum of fixed and variable costs for (1) the design periods generated by the theoretical model, and (2) the currently used design periods.

It was assumed for treatment plants that $\beta = 0.7$ and $i = 0.07$. The break-even point, for 10- and 20-year design periods, occurs when fixed costs per expansion are equal to 25 percent of variable costs per expansion at T=10, expressed by $0.25C[G(T=10)]$.

It was assumed in the case of interceptors that $\beta = 0.4$ and $i = 0.07$. Comparison of 25- and 50-year design periods showed that the break-even level occurs when fixed costs per expansion are equal to $0.75C[G(T=25)]$.

These break-even levels of fixed costs, for both treatment plants and interceptors, are higher than we would ordinarily expect to observe in practice. Also, the results are not particular sensitive to variations in β and i within the ranges indicated by Tables VII-1 and VII-2. Thus, the design periods determined by the model should be closer to the economically optimal solutions than those design periods which are presently being adopted in practice. [2]

In summary, the sensitivity analysis conducted in this section suggests that the results generated by the simple capacity expansion cost model are not significantly influenced by alternative model assumptions. The appropriate design period appears to be 10-12 years for treatment plants and 20-25 years for interceptors. If these design periods replaced those currently being used for determining grant eligibility, communities would be encouraged to adopt the design size which is socially desirable. At the same time, the total size of Federal funding needed to support the Construction Grant Program would be reduced, and more projects could be initiated in the short run for a given level of authorizations. In the next section, we will estimate the affect upon Federal funding of alternative grant-eligible design periods.

Implications for Federal Funding

Concern has been voiced over the size of the Federal commitment in the wastewater Construction Grant Program. The effect on net environmental benefits of alternatives for limiting this commitment, such as reducing grant-fund allotments, or reducing the Federal cost-sharing proportion, are presently unknown. However, such policies will certainly strengthen both municipal and industrial resistance to Federal wastewater treatment requirements, and encourage a reduced level of abatement activities.

Findings in earlier parts of this chapter suggest an attractive approach for limiting the Federal commitment. Reducing the grant-eligible design period is not only consistent with this objective, but could also encourage improved resource efficiency as well. Accordingly, the remaining portion of this section is devoted to estimating the effect on Federal funding requirements resulting from modifications in the grant-eligible design period for treatment plants and interceptors.

Treatment plants: Four options are considered. Grant-eligible design capacity is defined as follows for alternative h:

h = 1. Design capacity required to adequately service the sewered population as of 1973.

h = 2. Design capacity required to adequately service the estimated sewered population in 1977.

h = 3. Design capacity required to adequately service the estimated sewered population in 1983.

h = 4. Design capacity required to adequately service the estimated sewered population in 1993.

The first and second options provide for grant-eligible design capacity sufficient only to serve current and short-term population needs. The third option is a 10-year design period, consistent with the previous findings concerning the optimal design period. The fourth option reflects the present program.

The following terms are defined:

I_o = index of existing treatment plant design capacity.

I_h = index of grant-eligible treatment plant design capacity for option h above, where h = 1, 2, 3, 4.

C_h = index of grant-eligible costs of adopting option h, assuming community abatement needs are Federally funded only once.

Based on analyses of the 1973 Survey of Needs, it was determined in [6] that 60 percent of the existing sewered population is adequately served by waste treatment plants. Let this level of existing treatment plant capacity, designated by I_o, be equal to 6.0.

The grant-eligible design capacity in option 1 represents the treatment capacity required to adequately serve 100 percent of the existing sewered population. Since the index of treatment capacity required to adequately service 60 percent of the existing sewered population is represented by $I_o = 6.0$, it follows that the index of capacity required to adequately service 100 percent of the existing sewered population is $I_1 = 10.0$.

A recent sample [1] of 50 treatment plant construction plans, calling for approximately 20-year design periods, indicated the median design capacity to be 70 percent above the capacity needed to adequately service the existing sewered population. 2/ On the basis of this finding, the index of grant-eligible treatment plant design capacity for option 4 can be represented by $I_4 = 17.0$.

Further, the 20-year compounded annual growth rate, which generates a 70 percent increase in demand, is equal to 2.7 percent. This annual growth rate compounds to an 11 percent increase over four years (option 2), and compounds to a 30 percent increase over 10 years (option 3). 3/ Accordingly, the appropriate indexes of grant-eligible design capacity are $I_2 = 11.1$, $I_3 = 13.0$.

Summarizing, the following grant-eligible design capacity index numbers are appropriate:

$I_o = 6.0$

$I_1 = 10.0$

$I_2 = 11.1$

$I_3 = 13.0$

$I_4 = 17.0$

To calculate the index of Federal costs associated with any of the options, the approach taken in [6] is adopted. The grant-eligible cost index is essentially defined therein by

$$C_h = \left\{ I_h - I_o \right\}^{\beta} . \tag{8}$$

2/ The rationale for use of the median statistic is given in the Appendix.

3/ The implications of assuming linear rather than compound growth in demand are discussed in the Appendix.

This expression, in conjunction with the index numbers chosen, implies that all treatment plants have identical scale factors and reserve capacity requirements.

The results of applying equation (8) to the four funding alternatives are shown in Table VII-3, for different values of β. This table indicates that if $\beta = 0.7$, option 1 is 51 percent less expensive to the grantor than option 4: that is $(1-2.63/5.36)$ (100%) = 51%. Similarly, options 2 and 3 are 42 and 28 percent less expensive, respectively, than option 4.

Table VII-3
Indexes of Grant-Eligible Treatment Plant Construction Costs

β:	C_h: C_1	C_2	C_3	C_4
0.5	2.00	2.26	2.65	3.32
0.7	2.63	3.13	3.91	5.36
0.9	3.48	4.33	5.76	8.65

Given the cost indexes shown in Table VII-3, it is possible to estimate the savings in Federal funding from adopting any one of the three alternatives to the present grant-eligible design capacity program, represented by option 4. The following assumptions are made:

1. Actual grant-eligible costs for each option are proportional to the cost indexes generated from equation (8).
2. Implementation of the funding options for each treatment plant will involve direct calculation of eligible and ineligible construction costs, based on existing and projected demand. Grant-eligible costs will not be determined by multiplying actual construction costs by the ratio of grant-eligible design capacity to actual design capacity.

It is contended in the Appendix that if these assumptions are not satisfied in practice, then the actual size of Federal funding associated with options to the present program will be less than the estimates determined herein. As a result, the savings in Federal costs generated by the first three options can be considered lower-bound estimates.

The 1973 Survey of Needs [4] indicates that $18.3 billion (1975 prices) in grant-eligible treatment plant construction resources under option 4 are required to achieve mandated secondary treatment standards. Given the existing 75 percent Federal construction cost-sharing proportion, option 4 is therefore expected to incur a Federal funding outlay of $13.7 billion.

To determine the potential savings in Federal funding, from adopting options 1, 2, or 3, instead of option 4, we have to subtract from $13.7 billion the product of $13.7 billion and the ratio the cost index of options 1, 2, or 3, to the cost index of option 4. The range of potential Federal savings for any of these three options is estimated to be given by the upper and lower-bound cost indexes found in the appropriate columns of Table VII-3.

The potential savings from options to the present program are calculated to be given by the following ranges (billions of dollars):

Option 1: $5.5 - $8.2

Option 2: $4.4 - $6.8

Option 3: $2.8 - $4.5

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[4] The 1973 Survey of Needs rather than the more recent 1974 Needs Survey was used to estimate the resource requirements for option four, because of the belief that reported cost estimates in the later survey "greatly overstate the cost of meeting the 1983 goals of the FWPCA" [7]. Additionally, the earlier survey contained only grant-eligible needs, which is the appropriate category for our analysis, while the most recent survey included construction costs for all needs required to meet Federal treatment standards. Moreover, the analysis considers only those grant-eligible costs required to meet secondary treatment plant standards, since the funding options under consideration are not expected to generate variations in Federal requirements as a result of the need for higher treatment levels in water-quality limited areas [8].

Interceptors: Four options are considered. Grant-eligible design capacity is defined as follows for alternative j:

j = 1. Design capacity required to adequately service the existing sewered population as of 1973.

j = 2. Design capacity required to adequately service the estimated sewered population in 1993.

j = 3. Design capacity required to adequately service the estimated sewered population in 1998.

j = 4. Design capacity required to adequately service the estimated sewered population in 2023.

The first option provides grant-eligible interceptor design capacity only to service the existing sewered population. Options 2 and 3 are generated from previous findings on the optimal interceptor design period, which was shown to range from 20 to 25 years. Option 4 approximates the grant-eligible design period of the present program.

Construction of new interceptors, rather than additions to existing interceptors is considered, since this restriction coincides with the intent of the 1972 Act. Accordingly, the indexes of grant-eligible interceptor costs for each option are calculated from the following equation:

$$C_j^v = \left\{ I_j^v \right\}^{\beta} . \tag{9}$$

(The superscript v is used to distinguish interceptor design capacity and costs from equivalent treatment plant measures).

Based on a recent sample of 15 proposed interceptor projects, the median reserve capacity observed was 300 percent above current needs [1]. With a 50-year design period, this is equivalent to an annual compounded growth rate of 2.8 percent, which is consistent with the growth rate found for 20-year treatment-plant reserve capacity requirements. Using the same approach employed for treatment plants, and setting $I_1^v = 10.0$, the following grant-eligible design capacity index numbers are generated:

$I_1^v = 10.0$

$I_2^v = 17.4$

$I_3^v = 20.0$

$I_4^v = 40.0$

The results of substituting these index numbers into equation (9), for different values of β, are shown in Table VII-4.

Table VII-4

Indexes of Grant-Eligible Interceptor Construction Costs

C_j^v: β:	C_1^v	C_2^v	C_3^v	C_4^v
0.3	2.00	2.36	2.46	3.03
0.5	3.16	4.17	4.47	6.33
0.7	5.01	7.39	8.14	13.29

The 1973 Survey of Needs indicates that, under option 4, grant-eligible interceptor costs are equal to $15.0 billion (1975 prices). Application of the 75 percent Federal construction grant rate yields a Federal cost share of $11.3 billion.

Using this latter dollar figure in the same manner employed in the analysis of treatment plants, we calculate the range of potential Federal savings from adopting options 1, 2, or 3, instead of option 4, to be given by the following ranges (billion of dollars):

Option 1: $3.9 - $6.9

Option 2: $2.4 - $5.0

Option 3: $2.1 - $4.3

Conclusions

The results of the preceeding section indicate that adoption of the first options for treatment plants and interceptors is estimated to reduce the Federal commitment by approximately \$9.4 to \$15.1 billion, equivalent to a 38 to 60 percent reduction in funding treatment plants and interceptors compared to the present program. However these first options, by themselves, do not provide an incentive for communities to choose the optimal design period, and hence to provide the optimal level of reserve capacity. As a result, they can be expected to result in higher social abatement costs than are actually needed to meet mandated cleanup requirements.

Perhaps more importantly, these first options, by substantially reducing the share of construction costs borne by the Federal government, may lead to undesirable environmental effects in the longer run, even if short-run resistance to an implied "no-growth policy" and potential inequities among communities with different growth rates can be mitigated. Similar arguments apply to option 2 for treatment plants. 5/

5/ A recent study [9] argues that excess capacity for interceptor sewers should not be eligible for a Federal grant, owing to the incentive in the present system for communities (and private engineering firms working for localities) to overestimate reserve capacity requirements. Also, the study maintains that based on past experience, communities will pay for interceptor reserve capacity with their own funds if the project is locally cost effective. The first problem of concern, i.e., ensuring that future wastewater collection needs are objectively measured, is known to exist, but does not appear to be sufficient rationale for eliminating Federal funding. The second argument remains to be proven conclusively. If this argument is generally valid, then it would make sense to limit Federal funding to those socially desirable projects that would not be undertaken by communities on their own.

In any event, Section 211 of P.L. 92-500 already limits funding for sewage collection systems for replacement or rehabilitation of an existing collection system, or for a new collection system in an existing community. These restrictions tend to restrict the ability of communities to use Federal funding for subsidizing "continued suburbanization," a major concern indicated in [9].

On the basis of the dual objective of encouraging more efficient abatement resource allocation and limiting the size of the Federal commitment, it is suggested that the present program (the fourth option) be modified. Changes would be in the form implicit in option 3 for treatment plants and options 2 and 3 for interceptors. Savings in Federal funds from adopting a 10-year treatment plant design period (for grant eligibility) range from \$2.8 to \$4.5 billion. Adoption of a 20- to 25-year interceptor design period can be expected to save between \$2.2 to \$4.6 billion. Total savings are therefore estimated to range from \$5.0 to \$9.1 billion, equivalent to a 20 to 36 percent savings compared to the present funding program for treatment plants and interceptors.

Appendix: Elaboration of Assumptions Used in the Analysis

This appendix discusses in detail the sensitivity of four important assumptions used in the analysis of grant-eligible design capacity options for treatment plants and interceptors.

Sample Median Reserve Capacity: The analysis in this chapter used the sample median reserve capacity statistic, based on recent EPA audits, to forecast the expected size of reserve capacity requests.

A more accurate approach is to evaluate reserve capacity funding requests on an individual case-by-case basis. A less ambitious approach is to segment treatment plants and interceptors by the characteristics influencing the percentage size of reserve capacity requests.

Sufficient data were not available to permit undertaking either one of these two approaches. Accordingly, the median values for reserve capacity percentages are used instead of, for example, average values, in order not to distort the influence of small plants which tend to request relatively higher reserve capacity proportions compared to large plants.

These median values are consistent with an annual compounded growth rate of approximately 2.7 percent, which is a realistic estimate of local community growth assumptions. Moreover, it can be shown that if higher estimates of reserve capacity had been used, the savings in Federal funding for the options considered to the current program would have been at least as high as those estimates generated in the present analysis.

To demonstrate this contention, consider interceptors first. The model specifies a zero starting point for estimating the index of interceptor capacity expansion costs. Therefore, it is easy to show that as the reserve capacity index used for the present program increases, the ratio of the expansion cost index associated with options 1, 2, or 3, to the expansion cost index of the present program, declines. 6/ Accordingly, the Federal savings from adopting these options to the present program will increase as the present program's reserve capacity index increases.

6/ If linear rather than compound growth is assumed, this ratio also declines for option 1, but remains unchanged for options 2 and 3.

The case of treatment plants is more difficult to generalize, owing to the use of a non-zero starting point. For a significantly higher reserve capacity index than originally specified, the starting point becomes relatively less important, and Federal savings from alternatives to the present program will increase as described for interceptors.

The results are less clear-cut for modest increases in the reserve capacity index. For the case at hand, a sensitivity analysis was conducted using treatment plant reserve capacity of 100 percent instead of 70 percent for the current program. The results indicated that the estimated increase in Federal savings (from adopting the specified alternative design-period eligibilities) were less than 20 percent higher for any option to the current program. Further, a reserve capacity index of 50 percent for the current program generated reductions in Federal savings of less than 15 percent compared to original estimates.

Compound Growth Rate: The analysis assumes that the demand for treatment and collection services increases in a compound-growth fashion, that is, in equal percentage increments per year. If it had been assumed that the growth rate were linear, that is, increasing in equal absolute amounts each year, the Federal savings from options to the present program would have been equal to or slightly less than those savings calculated in the analysis.

Since the end points of demand as a function of time are fixed by options 1 and 4, use of a linear growth assumption would have affected only options 2 and 3 for both treatment plants and interceptors. For treatment plants, we would have used

$$I_2 = 10 + (17-10)(4/20) = 11.4.$$

Similarly,

$$I_3 = 10 + (17-10)(10/20) = 13.5.$$

The range of Federal savings for these options is then given by ($ billions):

Option 2: $4.1 - $6.5

Option 3: $2.3 - $4.0

These figures are approximately 10 percent less than those generated under the assumption of compound growth.

For the case of interceptors, a linear growth assumption leads to the finding that $I_2^v = 22.0$, and $I_3^v = 25.0$. The range of Federal savings for these two options is then estimated to be ($ billions):

Option 2: $1.09 - $3.9

Option 3: $1.4 - $3.2

These figures are approximately 20 percent lower than originally estimated for the case of compound growth.

Proportionality of Cost Indexes to Actual Costs: Based on this proportionality assumption, it was possible to calculate the dollar savings in Federal funding associated with each option, using only the existing estimate of grant-eligible costs associated with the present program. These costs were recently estimated by communities in light of the currently allowed design-period eligibilities for treatment plants and interceptors.

By reducing the grant-eligible design period, the options to the present program also tend to reduce the effective Federal share of construction costs compared to the present program. This means that the incentive for communities to choose overcapitalized and more socially costly abatement projects will be mitigated. Accordingly, these options can be expected to encourage communities to choose projects which generate lower construction costs, for any level of reserve capacity attained. Therefore, in practice, we can expect the amount of Federal savings associated with reductions in design-period eligibilities to be higher than previously estimated, since the affect of the reduction in the Federal cost-sharing proportion on the demand for wastewater collection and treatment resources was not taken into account.

Determination of Eligible Design Capacities and Costs in Practice: The analysis assumes that grant-eligible costs are determined in practice for individual projects by applying a capacity expansion cost function to allowed design size and to actual size. The ratio of these cost estimates represents the proportion of total costs which would be considered eligible for a Federal grant.

When eligible design size differs from actual size, it may be administratively difficult to use engineering estimates to directly calculate grant-eligible costs. An often suggested alternative is to simply set the proportion of grant-eligible costs equal to the ratio of eligible expansion size to actual size.

From the definition of economies-of-scale, the percentage increase in plant size exceeds the percentage increase in cost. Using the size-ratio approach, the Federal cost-sharing proportion declines as additional capacity is added beyond the grant-eligible size. Moreover, the absolute level of grant-eligible costs will decline as well, as capacity is increased.

Accordingly, use of expansion-size ratios in practice, instead of cost ratios, ensures that actual Federal costs of alternatives to the present program will be less than previously generated estimates, and hence the Federal savings will be larger.

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CHAPTER VIII

ANALYSIS OF THE INDUSTRIAL COST RECOVERY PROGRAM

P.L. 92-500 stipulates that all recipients of waste treatment services pay for their share of operation and maintenance costs through user charges. Also, industrial recipients of treatment services are required to pay for that portion of the Federal construction grant allocable to the treatment of industrial wastes. Industrial repayment of the Federal share of construction costs is known as cost recovery. Of course, the municipality is free to negotiate with industry to recover the local share of construction costs allocable to industry as well.

The recovery of O&M and construction costs from users of wastewater treatment facilities serves two important economic functions. First, revenues generated can be used to pay for operating and replacement costs, and also provide funds for amortizing the debt incurred to finance initial construction costs.

Second, user charges and cost recovery serve as price signals to both recipients and suppliers of treatment services. As such, the charges, if set appropriately, can act to distribute demand and allocate pollution abatement resources in an economically efficient manner. This chapter is primarily concerned with investigating the efficacy of the existing cost recovery program as a mechanism for satisfying the second of these economic functions.

Of primary concern in this regard are cost-recovery regulations which (1) allow municipalities to retain one-half of industrial cost recoveries, and (2) do not require that an interest charge be included in cost recoveries. The analysis indicates that as a result of these regulations, both the municipality and industry may be in a position to benefit at the expense of society as-a-whole.

The municipality may be able to lower the amount of construction costs which its residents have to bear by building facilities of sufficient size to service industrial users. Industry can negotiate with the municipality to obtain some share of the grantee's profits from industrial participation.

At the same time, industry receives a substantial subsidy from not having to pay an interest charge on its portion of the Federal grant 1/

As a consequence, both industry and the municipality may find it advantageous to ensure that public facilities are provided to service industry, even when private treatment would require less real resources. The extent to which industry can benefit from the use of public facilities depends upon the relative cost of private treatment, including the availability of tax-exempt financing, as well as its bargaining strength vis-a-vis the municipality. The extent to which the municipality can benefit from the use of joint facilities is directly related to both the industrial proportion of the work load, and to the degree of economies-of-scale which can be captured. Accordingly, the local cost burden of satisfying pollution control requirements will generally fall most heavily on small communities that do not service industry.

The analysis shows that the most effective and administratively simple way to mitigate the inefficiencies and inequities induced by the cost recovery program is to require that all industrial cost recoveries be returned to the U. S. Treasury, or to the Construction Grant Program. If this change is not forthcoming, it is desirable to make two other modifications in the existing cost recovery program.

First, 100 percent (rather than the presently required 80 percent) of retained cost recoveries should be held in reserve, to be used solely for funding approved wastewater treatment projects. (A project can receive EPA approval without receiving a grant, e.g., budget limitations may prevent Federal funding of a socially as well as locally desirable project.) This would prevent municipalities from using 20 percent of retained cost recoveries for funding activities unrelated to wastewater pollution abatement.

Second, the amount of funds accumulated in reserve should not be deducted from grant-eligible costs for the purpose of determining the size of the Federal grant. This would improve resource allocation by eliminating the financial bias which exists in the present program for communities to expend the reserve fund on projects that do not receive a Federal grant.

1/ Industry can also benefit from economies-of-scale in public treatment. Although this effect will encourage the construction of larger municipal facilities, and hence result in an increase in the size of the Federal construction grant commitment or a reduction in the number of fundable projects, it will not, by itself, induce an inefficient allocation of abatement resources.

The analysis of the interest subsidy issue indicates that, suprisingly, it does not appear desirable to require that interest be recovered from industry on its share of the Federal grant. The reason for this is that in the presence of income-tax advantages and higher monitoring costs in private treatment, and economies-of-scale and average cost pricing in public treatment, recovery of an interest charge would induce a financial bias in favor of private treatment. This outcome is not consistent with the apparent intent of Congress to encourage public treatment of industrial wastes, nor is it desirable on economic efficiency grounds.

Cost Recovery Model

In the current Construction Grant Program, the nominal local cost-sharing proportion of grant-eligible construction costs is 25 percent. However, communities are allowed to retain one-half of industrial cost recoveries collected against the Federal grant. Thus, the effective local cost-sharing proportion of grant-eligible costs is actually equal to or less than 25 percent, depending essentially upon the industrial-residential waste-load ratio. The objective of this section is to quantify the relationship between the effective local cost-sharing proportion and the fraction of the waste-load representing industrial users. 2/

Legislative provisions in the 1972 Act relevant to cost recovery effectively stipulate that:

(1) Cost recovery will be collected from industrial users of municipal facilities to repay that portion of the Federal grant allocable to the treatment of industrial wastewater. 3/

(2) The grant recipient will retain 50 percent of industrial cost recoveries collected against the Federal grant. 4/

2/ The original research on the development of this relationship was conducted for EPA by the National Bureau of Standards [1].

3/ P.L. 92-500, Section 204 (b)(1)(B).

4/ Ibid., Section 204 (b)(3).

Federal Regulations pursuant to the 1972 Act further govern existing cost recovery policy through the following requirements: 5/

(a) Industrial cost recovery will not include an interest charge.

(b) Cost recovery will be collected from industry in equal annual payments over the life of the treatment works or over 30 years, whichever is less.

(c) No more than 20 percent of retained cost recoveries will be used by the municipality for projects unrelated to wastewater treatment or collection.

(d) At least 80 percent of retained cost recoveries will be placed in a reserve fund (held in government-issued or government-guaranteed securities or accounts), the principal and interest earned to be used solely for funding grant-eligible construction projects "associated" with the project necessary to meet the requirements of P.L. 92-500.

(e) If a subsequent Federal grant is forthcoming, the unexpended balance in the reserve fund will be deducted from grant-eligible project costs for the purpose of determining the size of the grant. However, the fund need not be held until a grant is forthcoming; i.e., the fund may be used for eligible and approved costs apart from any grant.

In order to evaluate the effect of the industrial cost recovery program on municipal cost-sharing proportions, the following assumptions are made:

1. Industrial users of public treatment facilities are not considered part of the municipal segment. Thus, the grantee is defined as being equivalent to residential users only.
2. The first industrial cost recovery payment is to be made one year after local obligation of construction costs.
3. The municipality will keep precisely 80 percent of retained cost recoveries in the reserve fund.

5/ "Final Construction Grant Regulations, Construction Grants for Waste Treatment Works," Federal Register, Title 40, Part 35, February 11, 1974.

4. The municipality will expend the entire reserve fund on projects which do not receive a Federal grant.

5. The municipality will not recover from industry any portion of the nominal 25 percent share of construction costs initially borne locally.

The first assumption is made in order to distinguish the costs borne by local residents from those borne by industry. The second assumption is made for mathematical convenience. The third assumption is a realistic projection of how a municipality will choose to distribute retained cost recoveries. That is, a municipality will generally choose to define the legal minimum portion of retained amounts as being non-discretionary, (i.e., 80%), since these funds are restricted in use while discretionary funds are not restricted.

The fourth assumption also derives from the course of action which appears to be clearly in each community's best interests. 6/ If the reserve fund were retained for Federally funded projects, grant-eligible construction costs would have to be reduced by the size of the reserve fund, before the Federal construction grant rate was applied. With a 75 percent construction grant rate, this means that the Federal grant is reduced by 75 percent of the amount in the reserve fund. Thus, when the reserve fund is used to pay for projects receiving a Federal grant, the local cost share is reduced by only 25 percent of the size of the reserve fund, and not by the full amount in the fund. On the other hand, if the reserve fund is used to pay for projects which do not receive a Federal grant, the local cost share is reduced by the full amount held in reserve. Therefore, a reserve fund is four times as valuable to a municipality if it is used to pay for projects which do not receive a Federal grant, compared to the case in which the fund is used to pay for projects which do receive a Federal grant. 7/

6/ An approach developed in [2] quantifies the local cost-sharing proportion when the reserve fund is used in part or in total for funding grant-related projects.

7/ If the reserve fund is used to pay for projects receiving a Federal grant, the municipality would also incur a reduction in the amount of future retained cost recoveries, since this amount is based upon the size of the original Federal grant. This aspect of cost recovery would tend to reduce further the value of the reserve fund held for funding projects which receive a Federal grant.

The four assumptions just described are retained throughout the analysis. The fifth assumption, made initially to simplify the argument, is subsequently relaxed.

The following symbols are defined:

K = grant-eligible construction costs. 8/

θ = municipality's effective cost-sharing proportion of K.

Y = fraction of the total waste-load allocable to the treatment of industrial wastes.

F = amount (dollars) of cost recovery required to be collected from industrial users of the municipality's facility, and subsequently retained by the grantee.

$F(n,i)$ = present value of an annual cash flow equal to F/n, generated at the end of each year for n years.

i = municipality's opportunity cost of capital.

With a 75 percent Federal construction grant rate, in conjunction with local retension of one-half of industrial cost recoveries, the expression for θ can be written

$$\theta = 0.25 - \frac{F(n,i)}{K}. \qquad (1)$$

The symbol denoted by $F(n,i)$ can be expressed in terms of F as follows:

$$F(n,i) = ZF, \qquad (2)$$

8/ To simplify the exposition, all construction costs are considered eligible for a Federal grant.

where

$$Z = \frac{1-(1+i)^{-n}}{ni} \quad .$$

Further, based on legislative provisions (1) and (2) and Federal regulation (a) described previously, we interpret F to be given by

$$F = 0.5\ (0.75)\ YK. \tag{3}$$

Substituting equation (2) and (3) into (1), we find that

$$\theta = 0.25 - 0.375YZ. \tag{4}$$

Equation (4) represents the (effective) local cost-sharing proportion of construction costs, when the amount of funds recovered from industry is limited to the industrial portion of the Federal grant. This scenario is consistent with assumption 5.

Now suppose that the municipality also recovers from industry the nominal 25 percent share of construction costs initially borne by the locality (including interest), but allocable to industrial use of public facilities. In this case, θ in equation (4) is reduced by $0.25Y$. 9/

We assume that recovery of both the Federal share (without interest) and the local share (with interest) of the allocable construction costs from industry results in the lower bound for θ . We also assume that recovery of only the allocable Federal share (without interest) of construction costs results in the upper bound for θ . Therefore, we can write

$$0.25(1-Y) - 0.375YZ \leqq \theta \leqq 0.25 - 0.375YZ. \tag{5}$$

9/ If only the principal amount of the local share of construction costs allocable to industry is recovered, hence no interest on the local share is charged to industry, θ in equation (4) would be reduced by $0.25YK(n,i)$, where $K(n,i)$ is defined in a similar manner to $F(n,i)$.

TABLE VIII-1

Municipal Cost-Sharing Proportions

Y	θ	Total Cost-Sharing Proportions (ϕ)		
		$\rho = 0.1$	$\rho = 0.5$	$\rho = 0.9$
0.0	0.25	0.93	0.63	0.33
0.2	0.18	0.74	0.49	0.24
0.4	0.10	0.55	0.35	0.15
0.6	0.03	0.36	0.22	0.07
0.8	-0.04	0.18	0.08	-0.02
1.0	-0.12	-0.01	0.06	-0.11

List of symbols:

Y = industrial proportion of the waste load.

θ = effective municipal cost-sharing proportion of construction costs.

ϕ = effective municipal cost-sharing proportion of total costs.

ρ = ratio of construction to total costs.

Quantitative results for θ are shown in Table VIII-1. It is assumed therein that $n = 30$, and $i = 0.10$. Also, we assume in the table that the industrial share of all local costs is recovered from industry. Accordingly, θ is given by the term on the left-hand side of equation (5).

The second column in Table VIII-1 represents the municipal cost-sharing proportion of construction costs θ, for the different levels of industrial participation shown in the first column, and designated by Y. The remaining columns represent ϕ, the municipal cost-sharing proportion of total costs, (construction as well as operating and maintenance) as a function of both Y and the ratio of grant-eligible to total costs, denoted by ρ.

Table VIII-1 indicates that θ declines as Y increases. 10/ In other words, for any given treatment plant size, the local cost burden will decline as the industrial proportion of the waste load increases. Further, communities of equal residential size but having unequal levels of industrial participation will presumably build different size plants, with larger facilities being provided in the more industrialized communities. Of course, in these cases, the communities building the larger facilities will bear a lower proportion of construction costs.

Each of these results is desirable on both economic efficiency and equity grounds. Unfortunately, however, the cost recovery program tends to overcompensate municipalities for providing industrial capacity. As a consequence, biases are created for municipalities to overbuild and to overcapitalize treatment facilities. Also, per capita residential treatment costs will tend to be higher in smaller, non-industrialized communities.

The overcompensation factor inherent in the cost recovery program is now demonstrated. Grant-eligible construction costs are denoted here by $K_o + \Delta K$, where

K_o = construction costs required to service only residential users.

ΔK = additional construction costs required to service industry.

10/ Note that the extent to which economies-of-scale can be captured does not directly affect θ. However, the magnitude of construction costs required to service a given waste load is, of course, affected by this factor. Presumably then, economies-of-scale will be taken into account in determining the appropriate plant size to build, and hence will affect the resulting level of industrial participation. Nevertheless, for any given plant size, θ only depends upon the distribution of the waste load between residential and industrial users, and the values assumed by n and i which determine Z.

In the absence of industrial participation, the municipality's share of grant-eligible costs is equal to $0.25\ K_o$. In the presence of industrial participation, the municipality initially bears costs equal to $0.25(K_o + \Delta K)$. Therefore, $0.25\Delta K$ represents the added grant-eligible costs initially borne by the municipality in the presence of industrial participation.

The municipality will subsequently recover and retain from industry an amount equal to $0.375YZ(K_o + \Delta K)$, which represents one-half of the Federal share of construction costs allocable to industry, and an amount equal to $0.25Y(K_o + \Delta K)$, which represents the industrial share of construction costs that are initially borne locally. Let Δk be the additional construction costs ultimately borne by the municipality in servicing industry. From the preceding argument, we can write

$$\Delta k = 0.25\,\Delta K - 0.375YZ\ (K_o + \Delta K) - 0.25Y\ (K_o + \Delta K). \qquad (6)$$

In the presence of constant returns to scale, the following relationship applies:

$$Y\ (K_o + \Delta K) = \Delta K \qquad (7)$$

Substituting (7) into (6) and dividing through by ΔK yields

$$\frac{\Delta k}{\Delta K} = 0.375Z\quad .$$

Since Z is positive, the community can reduce the local share of construction costs by inducing industrial participation 11/. For example, given that $n = 30$ years and $i = 0.10$, the municipality could make a profit of almost 12 cents on each dollar of incremental capacity provided to service industry, if the municipality recovers the industrial share of construction costs initially borne locally 12/.

11/ This result can also be inferred from Table VIII-1, where it is seen that for a given increase in Y, the proportional decline in θ exceeds the proportional decline in 1-Y.

12/ It can be easily demonstrated that this rate of profit is even higher in the presence of economies-of-scale, because in this case $Y(K_o + \Delta K) > \Delta K$.

As a consequence of this finding, we conclude that the existing cost recovery program has the following adverse affect on the allocation of abatement resources and on the distribution of Federal grant funds:

1. Communities have an economic incentive to encourage industrial use of public facilities, since the absolute amount of costs borne by the communities can be reduced by servicing industry. As a result, an additional capital bias is introduced into the treatment plant design and maintenance decision-making process. Further, required Federal construction grant funds will increase (or the number of fundable projects will decline) owing to the incentive for municipalities to build joint wastewater treatment facilities to service industry.

2. Communities have an economic incentive to undercharge industry relative to the incremental costs required to service them. In this way, both the municipality and industry can benefit (a) at the expense of the Federal government, by sharing the proceeds of the Federal subsidy, and (b) at the expense of society as-a-whole, if industry is induced to treat publicly even though private treatment requires less real resources.

Accordingly, the retention of one-half of industrial cost recoveries by municipalities has an adverse effect upon economic efficiency, equity, and upon the size of the Federal cost share needed to induce mandated levels of pollution abatement. It would appear that the most effective and administratively simple solution to this problem is to require that all industrial cost recoveries be returned to the U. S. Treasury, or to the Construction Grant Program for redistribution to the highest priority water pollution control projects.

Adoption of this recommendation would, in mathematical terms, be equivalent to eliminating the second term on the right-hand side of equation (6). As such, the additional construction costs ultimately borne by the municipality as a result of servicing industry would then be simply equal to initial local construction costs not paid for by the Federal government, less the amount of capital user charges collected from industry.

For example, suppose that the municipality is not allowed to retain any part of industrial cost recoveries. Also, suppose that we have a situation defined by the presence of either average cost pricing and constant returns to scale, or marginal cost pricing and economies-of-scale. (In both of these cases, industry pays the full resource cost associated with treating its wastewater.) It follows from equation (6) that $\Delta k = 0$ if user charges are collected from industry to pay for their share of local construction costs. Thus, the abolishment of local retension of industrial cost recoveries results in the elimination of (1) the financial bias (induced by cost recovery provisions) for municipalities to overbuild public treatment facilities, and (2) the tendency for municipalities to undercharge industry (apart from the Federal interest subsidy) for using public treatment facilities.

Suppose that the regulation which allows communities to keep one-half of industrial cost recoveries is retained. In this case, there is no easy way to modify the cost recovery program to account for the previously noted deficiencies with respect to the (1) overcapitalization bias, and (2) undercharging of industry. However, if the legal provision relating to retension of cost recoveries is not abolished, then the following issues become relevant:

1. Communities can use up to one-fifth of retained cost recoveries for projects and activities unrelated to the collection or treatment of wastewater.

2. It is generally advantageous for a community not to accumulate its reserve fund, but rather to expend the fund on pollution control projects which will not receive a Federal grant. In this way, the community can reduce its share of abatement project costs by the full amount of the reserve fund, denoted by F_r. Otherwise, if the fund is held for projects receiving a Federal grant, the size of the grant will be given by $0.75(K - F_r)$, and the reserve fund will then reduce the local cost share by only $0.25F_r$.

In regard to the first of these two issues, it is difficult to see the logic in allowing communities to use part of what amounts to Federal construction grant funds for purposes totally unrelated to the abatement of wastewater pollution. Patently, the 20 percent discretionary fund allowance should be eliminated, and all retained cost recoveries should be held in the reserve fund.

Consider the second issue. We have shown that a significant financial bias exists for communities to use the reserve fund to pay for projects that will not receive a Federal grant. Owing to this financial bias, the projects chosen to be so funded may well have a low priority, in real resource terms, both locally and nationally. Moreover, any intent to encourage some additional degree of community self-sufficiency in the funding of future facility construction projects, through accumulation of cost recoveries, is hampered by this local incentive to periodically deplete the reserve fund. Accordingly, it appears desirable that the amount of funds held in reserve not be deducted from grant-eligible construction costs for the purpose of determining the size of the Federal grant. This would eliminate the financial bias in favor of using reserve funds for non-grant related projects. Communities would then have a significantly greater incentive than presently exists to accumulate their reserve funds, and to subsequently use their reserve funds on projects which are locally cost-effective (in terms of local abatement benefits and social resource costs), thereby resulting in improved allocation of abatement resources.

Resource Allocation Effects of Cost Recovery on Industry

The previous section analyzed the effect of various elements of the cost recovery program on the allocation of abatement resources by municipalities. In this section we evaluate one important element of cost recovery which indirectly affects the size of the industrial waste load generated, and directly affects industry's choice of public versus private treatment.

The cost recovery element of concern provides that industry need not pay an interest charge on its portion of the Federal construction grant. If, as a result of this implicit subsidy, the costs borne by industry are disproportionately low compared to the real resource costs required to service industry in public treatment, a financial bias is said to be created.

This financial bias encourages an inefficient allocation of resources in two ways. First, industry may be induced to use public facilities in cases where private treatment would require less real resources. Second, even when public treatment is the least social-cost treatment option, the appropriate incremental costs of servicing industry will not be internalized. As a result, higher levels of water pollution than are socially desirable will be generated, because final products that are pollution related will tend to be underpriced and overproduced.

In order to mitigate the distortions in resource allocation caused by the first of these effects, it is desirable that the ratio of costs borne by industry in public and private treatment be equal to the ratio of real resource costs needed to service industry in each activity. This relationship would encourage the appropriate allocation of abatement resources, between public and private facilities, for whatever the level of wastewater generated. In the absence of this relationship, a financial bias in favor of public or private treatment is created, because relative prices would not reflect relative abatement resource requirements. 13/

In the Legislative Hearing held prior to the enactment of P.L. 92-500, the Committee on Public Works, House of Representatives, stated that "each industrial user of a public system would pay a charge that would include not only that share of operating and maintenance costs allocable to such user but which would also be sufficient to recover that portion of the Federal share of the capital cost of the facility allocable to such user ..... subsidy of private industry through the waste treatment works grant program would be haphazard and inappropriate." [3] A few sentences later, the "committee affirmatively concluded that capital costs recovered from industry should not include an interest component." [3]

The impact of this interest subsidy on the relative abatement construction costs borne by industry in public and private treatment is determined below. Taken in conjunction with Federal income-tax considerations, these calculations will reveal the conditions under which the interest subsidy creates a financial bias in favor of public treatment. 14/

The following assumptions are made:

1. All cost recoveries are returned to the Federal government. Equivalently, for calculation purposes, we could assume that industry does not share in any local profit on cost recovery.
2. Industry's share of Federal and local construction costs incurred in public treatment is recovered over 30 years.

13/ Note that the creation of a financial bias does not guarantee that a misallocation of abatement resources will, in fact, occur, for the given level of effluent generated. For example, suppose that the socially optimal solution is for each firm to treat its wastewater effluent entirely in one activity (i.e., publicly or privately). As long as the activity requiring less real resources imposes lower costs on each particular firm, the appropriate allocation of resources between public and private treatment will be encouraged.

14/ Owing to differences in State tax codes, and also to the minor effect of State corporate income taxes on the relative costs of public and private treatment, only Federal income taxes are quantified in the model.

3. The municipal cost of capital is 6 percent.

4. The Federal cost of capital is 7 percent.

5. Marginal cost pricing is employed in public treatment.

6. Real resource (construction) costs required to service industry in both public and private treatment are equal to $100.00.

From assumption 5, we can infer that the prices charged industry in public treatment are equal to the incremental costs required to service industry. Further, it follows from assumption 6 that if we find that the (construction) costs borne by industry in public and private treatment are unequal, a financial bias in favor of one of these activities will have been shown to exist. 15/

The construction costs borne by industry in public treatment are found by determining the present values of specific public treatment cost elements, taking into account Federal income-tax considerations. These present values, representing discounted cash flows, are equivalent to the cost that industry would be willing to pay now (as a non-tax deductible expense) in order to forego the periodic payments implied by each of the cost elements.

The present values are calculated using two alternative figures for the firm's opportunity cost of capital, i.e., the after-tax discount rate: 4.5% and 9.0%. 16/ For example, Table VIII-2 shows that if a firm's (after-tax) discount rate is 9 percent, payment of the allocable Federal share without interest, plus the allocable local share with interest

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15/ The equality assumption between the real costs of public and private treatment (at $100.00) is made for expositional purposes only. In fact, any combination of real resource costs would suffice. In this more general case, as indicated previously, a financial bias is shown to exist if the ratio of costs borne in each activity is not equal to the ratio of real resource costs incurred in each activity. In the presence of numerous corner solutions (each firm treating entirely publicly or privately), the primary concern should be that the activity requiring a higher level of real resource costs also imposes a higher cost burden on industry. The equality of the ratio of real resource costs incurred in each activity to the ratio of costs borne would then be of secondary concern.

16/ Calculation of these present values was initially done by Charles Marshall of the JACA Corporation.

TABLE VIII-2

Present Value of Industrial Construction Costs Incurred in Public Treatment: Allocable Costs = $100.00

	After-tax Discount Rates	
Construction Cost Element *	4.5%	9.0%
75% Federal Share	$21.18	$13.35
25% Local Share	7.06	4.45
6% Interest on Local Share	7.57	5.70
Existing Construction Costs Paid by Industry	$35.81	$23.50
7% Interest on Federal Share	$26.73	$18.15
Potential Construction Costs Paid by Industry	$62.54	$41.65

* For example, the 75% Federal Share cost element is calculated as follows:

$21.18 = $16.29 ($3.33)(0.75)(1-0.48),

Where $16.29 is the present value of a 30-year annuity, at 4.5%, paying $1 per year.

$3.33 is the annual payment of the original $100 cost.

0.75 is the Federal share.

0.48 is the Federal tax rate.

at 6 percent, imposes costs (in present value terms) of \$23.50 on industry. Payment of interest at 7 percent on the Federal share increases the amount of costs borne by industry in public treatment to \$41.65. In both cases, the present value of the potential construction costs borne by industry is less than \$100.00 (the social marginal cost of servicing industry), because the interest charges are less than the market rate confronting industry and the expenses incurred by industry are tax deductible.

For comparison purposes, we now calculate the construction costs borne by industry in private treatment. [17] The following assumptions are made:

1. Funds used to finance the construction of the private abatement projects are borrowed in the money market.
2. The cost of borrowing is 10 percent in the corporate bond market, and 6 percent in the tax-exempt market. Tax-exempt financing refers to Industrial Revenue Bonds, issued by a municipal authority for private industry. Responsibility for repayment of principal and interest rests with industry, and bondholders are not required to pay Federal income taxes on the interest earned by the bonds.
3. Asset lives and the payback period for principal and interest lie within the range of 20 to 30 years.
4. The choice between the 7 percent investment tax credit and rapid amortization [18] was determined by finding that option which incurred lower private costs for a given combination of parameter values, i.e. asset life, payback period, interest rate, discount rate.

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[17] This analysis is further complicated by three factors: (1) Continuing modifications in the income-tax code; (2) obscure tax regulations; and (3) allowable tax deductions specified in dollar, rather than percentage terms. Although it is believed that the net effect of these factors on our findings is small, it would be prudent to consider the results presented here as first-order approximations.

[18] Rapid amortization rules allow an asset having a useful life of 15 years or less to be depreciated over a five-year period, using the straight-line method. Assets having useful lives in excess of 15 years may be depreciated under rapid amortization for only that portion of the asset cost allocable to the 15-year period. The remainder is subject to normal depreciation rules.

As before, we specify two alternative discount rates: 4.5%, and 9.0%. Also, the real construction costs of private and public treatment are equalized at $100.00.

Table VIII-3 shows, for example, that with a 9% discount rate and a 10% interest rate on corporate borrowing, the costs borne by industry, which result from a $100.00 investment in pollution abatement, range from $34.43 to $49.78, in terms of present values. The lower-bound figure occurs when the asset life is 20 years, and the payback period is 30 years. The upper-bound figure occurs when the asset life is 30 years, and the payback period is 20 years. Note again that the costs borne by industry are less than the social costs ($100.00) due to tax deductibility of expenses and interest charges which are below market rates.

Comparison of Tables VIII-2 and VIII-3 indicates that under the existing cost recovery program (for a given discount rate), the abatement construction costs borne by industry in public treatment are less than the costs borne in private treatment. For example, given a 4.5% discount rate, public treatment costs are estimated to be $35.81, while private treatment costs range from $45.25 to $69.57. Similarly, with a 9.0% discount rate, public treatment costs are found to be $23.50, while private treatment costs range from $24.23 to $49.78. Since it was orginally postulated that the real construction costs incurred in each activity are equal, it follows that in our example a financial bias is seen to exist in favor of public treatment.

Suppose that the cost recovery program were modified such that industry is required to pay a 7 percent interest charge on its share of the Federal grant. The tables show that, for firms that can take advantage of tax-exempt financing, a financial bias is then generated in favor of private treatment 19/. In this case, public treatment costs borne by industry are $62.54 for a 4.5% discount rate, and $41.65 for a 9.0% discount rate, while comparable private treatment costs range from $45.25 to $53.41 for a 4.5% discount rate, and from $24.23 to $37.25 for a 9.0% discount rate.

19/ It is well known that tax-exempt financing is inefficient, in the sense that the government tax-revenue losses exceed industry's gains from the interest subsidy. Also, the interest subsidy inherent in tax-exempt financing is of dubious effectiveness as an incentive to control pollution, because the subsidy only reduces the cost of an already unprofitable investment. At the same time, private tax-exempt financing raises the cost of borrowing for competing debt instruments, mostly municipal bonds. Finally, tax-exempt financing is usually available only to the larger private firms. Because of these reasons, it would appear desirable to eliminate the use of tax-exempt financing for pollution control investments, apart from any changes in the cost recovery program.

TABLE VIII-3

Present Value of Industrial Construction Costs Incurred in Private Treatment: Allocable Costs = $100.00

	After-Tax Discount Rate	
Interest Rate Paid on Private Borrowing	4.5%	9.0%
6% Tax-Exempt Rate	$45.25 - $53.41	$24.23-$37.25
10% Regular Corporate Rate	$66.25 - $69.57	$34.43-$49.78

It has been estimated that one-half of industry's construction costs for controlling pollution will be financed in the tax-exempt bond market during the next five years [4]. Accordingly, based on the example presented, it does not appear desirable to recover an interest charge from industry on its share of the Federal grant, owing to the financial bias which would be created in favor of private treatment for those firms that can take advantage of tax-exempt financing.

In fact, the example actually understates the bias created in favor of private treatment when interest is recovered from industry on its share of the Federal grant. This is the case because several factors were not considered which tend to favor private treatment.

First, ambient monitoring costs are lower when industry uses public facilities, since the number of outfalls to monitor is reduced. Ambient monitoring costs are generally borne by the Federal (and local) government, hence in the absence of a monitoring fee, industry will not take these costs into account in deciding whether to use public or private facilities.

Second, State income taxes generally favor private treatment, because the depreciation period of a private abatement investment is usually shorter than the payback period used by a public facility. However, this bias is offset to some extent in States that require that property taxes be paid on pollution control investment projects.

Third, in practice, industries using public facilities usually will be charged on the basis of average, not marginal costs. In the presence of economies-of-scale, average costs will exceed marginal costs at any treatment plant design size 20/. Hence, industry will tend to be overcharged relative to incremental resources required in public treatment, excluding the effect of the interest subsidy.

20/ At a given treatment plant design size, the ratio of average costs to marginal costs increases as the degree of economies-of-scale increases. Thus, in the presence of average cost pricing, the higher the degree of economies-of-scale, the greater will industry be "overcharged" relative to incremental resources required. At the same time, even in the presence of average cost pricing, the absolute amount of costs charged to industry declines as economies-of-scale increases.

Thus, the failure to include an interest charge in the price of public treatment services is offset by (1) a similar failure in the price mechanism to reflect lower monitoring costs in public treatment, (2) State income-tax regulations favoring investment over expense items, and (3) the use of average cost pricing, by municipalities, in the presence of economies-of-scale. Accordingly, if an interest charge based on the Federal grant were recovered from industry without accounting for these three factors, the financial bias in favor of private treatment would then be higher than was estimated previously in our example. Thus, it is concluded that in the continued presence of tax-exempt financing, it would be inappropriate to require that interest be recovered from industry on its share of the Federal grant.

In fact, even if tax-exempt financing were eliminated, Tables VIII-2 and VIII-3 imply that taking into account monitoring costs, State income-tax considerations, and average cost pricing, a financial bias would still be created in favor of private treatment if interest on industry's share of the Federal grant were recovered.

Owing to economies-of-scale, it can be expected , a priori, that the real resource cost of industrial treatment is lower in public facilities. As a consequence, it does not appear desirable to generate a financial bias in favor of private treatment. Therefore it is concluded that given a choice between no interest recovery, and full interest recovery on the portion of the Federal grant allocable to industry, the former option is preferable.

Nevertheless, the analysis suggests that the optimal solution probably would be to recover from industry some part of the Federal interest allocable to industry. Unfortunately, determination of "appropriate" proportion of the interest component to be recovered from industry is an extremely complicated theoretical and empirical problem, and lies beyond the scope of the present study.

References: Chapter VIII

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